PETROLOGY OF A PERMO-CARBONIFEROUS SECTION IN NORTHERN JASPER NATIONAL PARK

JAMES THADIUS WALASKO, B.SC.

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PETROLOGY OF A PERMO-CARBONIFEROUS SECTION IN NORTHERN JASPER NATIONAL PARK

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY
by
JAMES THADIUS WALASKO, B.Sc.
EDMONTON, ALBERTA
1962

UNIVERSITY OF ALBERTA

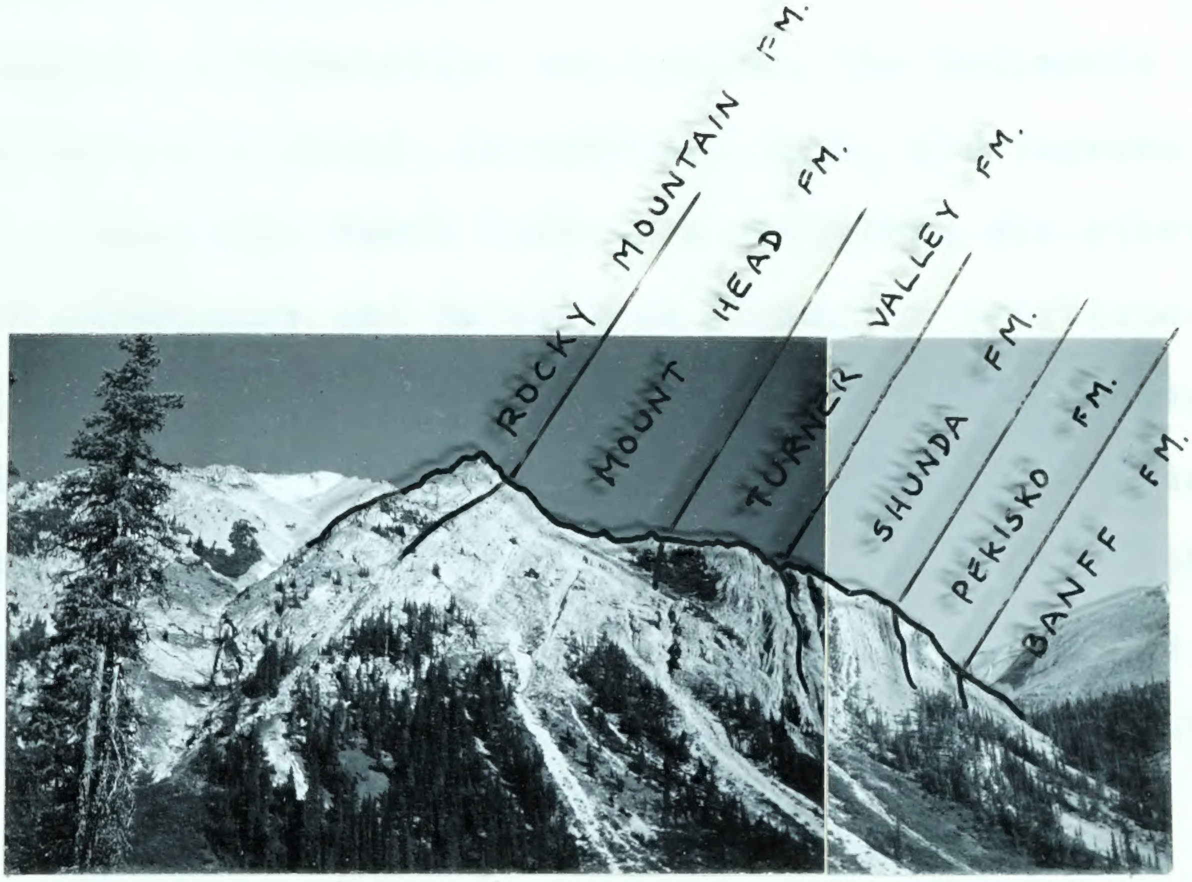
FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Petrology of a Permo-Carboniferous Section in Northern Jasper National Park", submitted by James Thadius Walasko, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

FRONTISPIECE

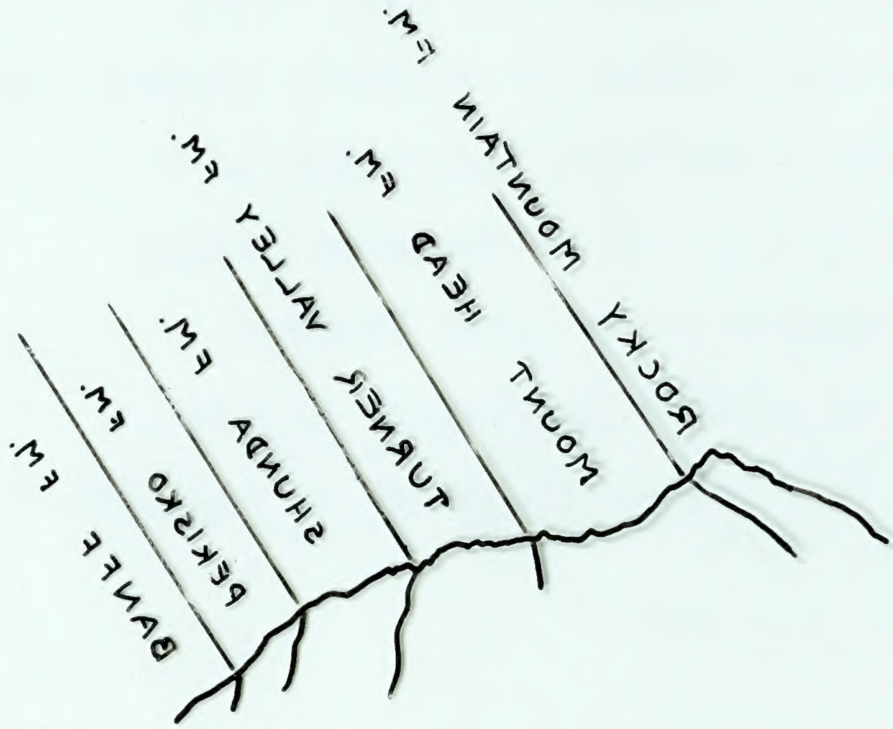
View Of The Thornton Creek Section Looking Northward.

(Geological Survey Of Canada Photograph)



ROCKY MOUNTAIN FM.
MOUNT HEAD FM.
TURNER VALLEY FM.
SHUNDA FM.
PEKISKO FM.
BANFF FM.

FRONTISPIECE



View Of The Thornton Creek Section Looking Northward.

(Geological Survey Of Canada Photograph)

ABSTRACT

A section of Permo-Carboniferous rocks located near the headwaters of Thornton Creek in northern Jasper National Park was examined to reconstruct the conditions of sedimentation, and to investigate the diagenesis and alteration of these rocks. Depositional environments were interpreted from textural, mineralogic, and faunal information.

Mississippian sedimentation was cyclic, the sediments reflecting shallow-water shoal, intershoal, bank, and lagoonal environments. Uppermost Banff Formation sediments are alternating shallow-water limestones and dolostones formed in restricted environments. A shoal area with periodic restriction of the waters marked Pekisko time in the Jasper area. Shunda Formation sediments contain much ooze; the area during this time was probably very similar to the protected shelf lagoons existing on the Bahama Banks today. Turner Valley and Mount Head Formations are highly dolomitized.

Permian sedimentation began with the deposition of a basal conglomerate over an erosion surface, after which the sediments consist of a shallow-water deposit of spicular chert overlain by a quartzose sandstone, which possibly indicates a regressing sea.

Dolomitization probably took place at an early diagenetic stage, and may have been caused by magnesium-rich solutions resulting from evaporitic concentration of normal sea water in restricted environments.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge the help of Dr. J. F. Lerbekmo, under whose supervision the thesis was written. Dr. S. J. Nelson provided criticism and edited the manuscript, and Dr. F. A. Campell assisted in the X-ray work.

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INTRODUCTION

GENERAL STATEMENT

This thesis is a petrologic study of an unfaulted, well-exposed section of Mississippian and Permian sedimentary rocks about 21 miles N23°W of Jasper in Jasper National Park at longitude 118°17'30" West and latitude 53°9'34" North (Fig. 1,7). The section is along a mountain spur immediately north of a stream unofficially named Thornton Creek, which drains northeastward from Mount Thornton into the Snake Indian River, and is accessible only by foot or helicopter transportation (Fig. 2 and Frontspiece). Dr. E. W. Mountjoy and the writer measured and sampled the section on July 12, 1960 while the writer was a student assistant employed by the Geological Survey of Canada.

The Thornton Creek section occurs in the hanging wall of the Colin Thrust, which in this area contains strata ranging in age from Devonian (Flume and Cairn Formations) to Triassic (Sulphur Mountain Formation). To the southwest the succession is broken by the Chetamon Thrust, and Lower Cambrian Gog sandstones occur in fault contact above the Triassic rocks.

Mississippian strata are predominantly limestones, dolostones and mixed calcite-dolomite rocks. Permian rocks are cherts and sandstones.

OBJECTIVES

The principal objectives of the study were twofold:

1. To reconstruct the sedimentation and investigate the diagenesis and alteration of these rocks.
2. To classify the sedimentary rocks.

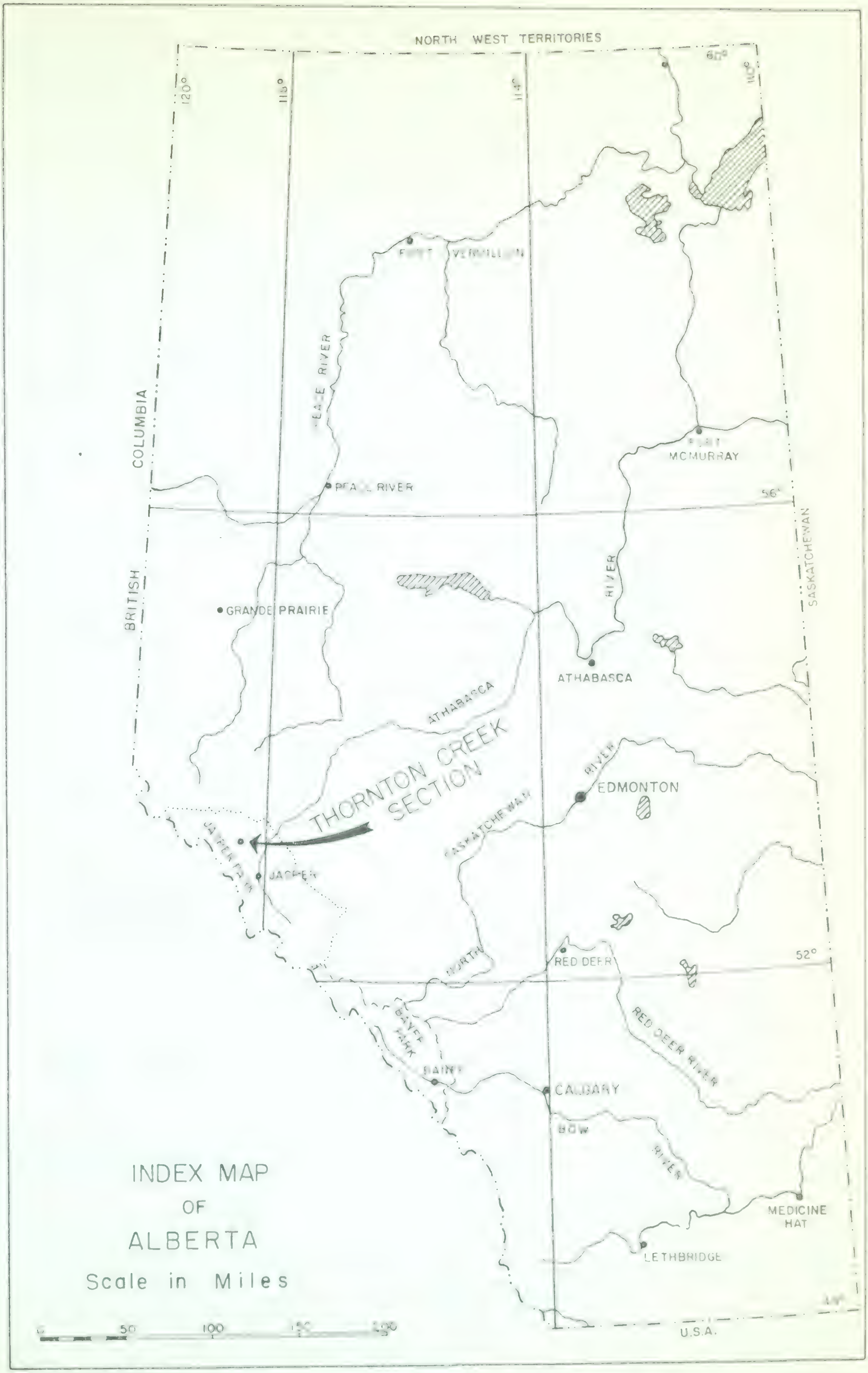
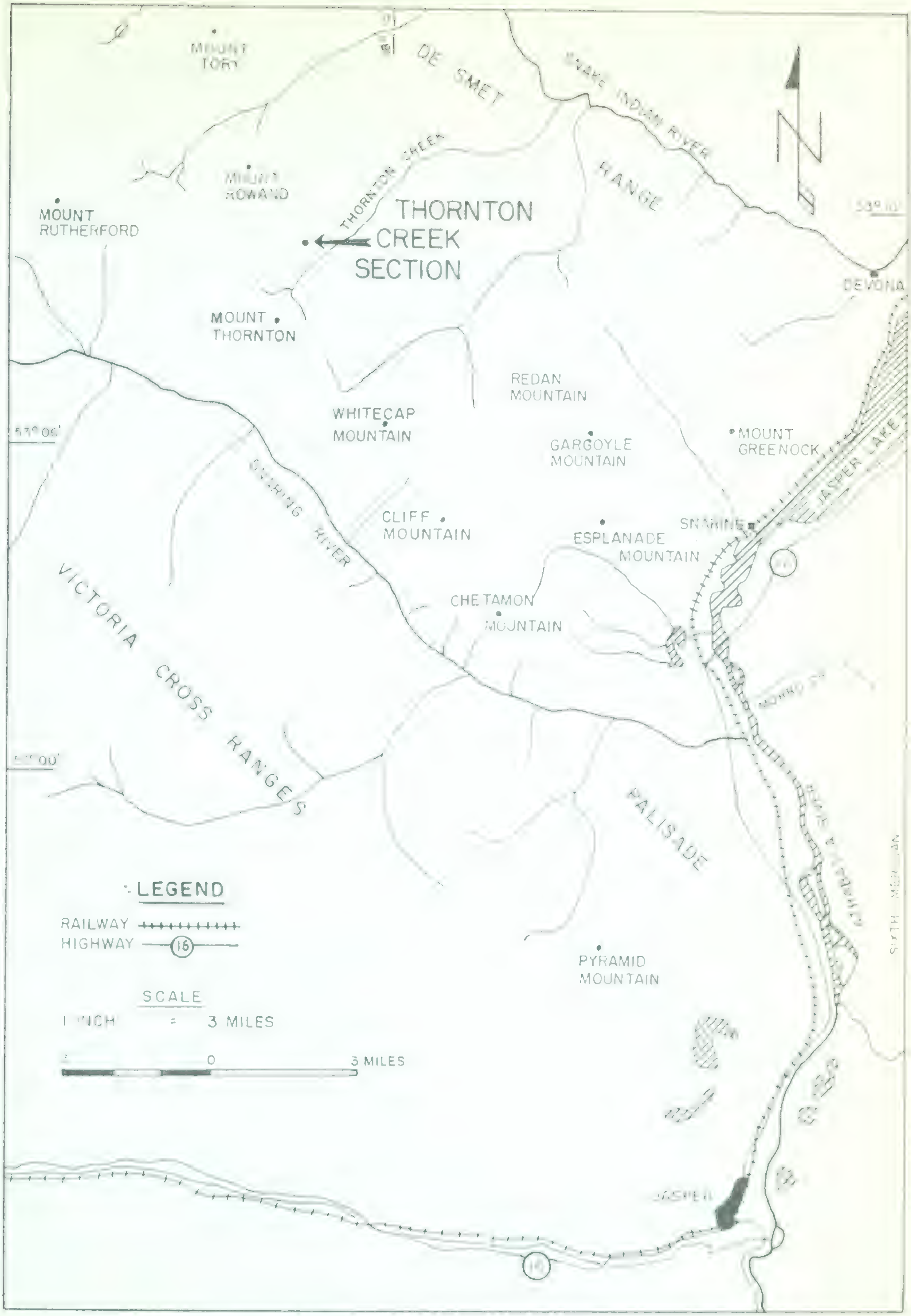

NORTH WEST TERRITORIES
60°
120°
118°
114°
110°
FORT VERMILION
PEACE RIVER
COLUMBIA
BRITISH
FORT MCMURRAY
PEACE RIVER
56°
SASKATCHEWAN
RIVER
GRANDE PRAIRIE
ATHABASCA
ATHABASCA
THORNTON CREEK SECTION
RIVER
EDMONTON
SASKATCHEWAN
JASPER PARK
JASPER
NORTH
RED DEER
52°
RED DEER RIVER
BANFF PARK
BANFF
CALGARY
BOW
RIVER
MEDICINE HAT
LETHBRIDGE
49°
U.S.A.
INDEX MAP
OF
ALBERTA
Scale in Miles
0
50
100
150
200

FIGURE I.



LOCATION MAP OF JASPER AREA

FIGURE 2

METHODS AND PROCEDURES

The methods of study employed include both field and laboratory investigations:

1. Field measurement and description of the section.
2. Thin section examination.
3. Quantitative analyses for calcite and dolomite.
4. Identification of clay minerals by X-ray diffraction.
5. Insoluble residue study.

STRATIGRAPHY

INTRODUCTION

Permo-Carboniferous strata underlie extensive areas of Western Canada. Mississippian sediments are more widespread than Permo-Pennsylvanian strata which are generally confined to the Rocky Mountains in west central Alberta, but are more extensive in northwestern Alberta (Nelson, 1961; Halbertsma and Staplin, 1960). In the Rocky Mountains of west central Alberta, Permo-Carboniferous strata lie unconformably between the Devonian and Triassic systems (Harker and McLaren, 1958; McGugan, 1961). Eastward from the Rocky Mountains, Triassic, Jurassic, and Lower Cretaceous strata progressively overlie Permo-Carboniferous sediments until the latter thin out owing to pre-Lower Cretaceous erosion, which largely determines present areal limits of these sediments. Generalized Permo-Carboniferous nomenclature in western Canada is shown in Table 1.

MISSISSIPPIAN SYSTEM

The standard section of the Mississippian system in western Canada near Banff, Alberta is comprised mainly of argillaceous and calcareous strata. East to west facies changes and lack of palaeontologic control has hindered correlation of other sections with the standard section. However, as early as 1929 Kindle recognized approximate Banff area equivalents in Jasper National Park. Allan et al (1932) confirmed Kindle's work after Raymond (1930) had proposed new formational names for the Permo-Carboniferous in this area. Correlations to the Jasper area have more recently been extended from the Banff area and the southern Alberta plains by Nelson and Rudy (1959), Rudy (1958), Nelson

GENERALIZED PERMO - CARBONIFEROUS NOMENCLATURE IN WESTERN CANADA

SYSTEM	STAGE	SASKATCHEWAN BRINDLE 1962	SOUTHERN PLAINS OF ALBERTA PENNER 1958		BANFF NELSON 1961 MCGUGAN 1961		JASPER DRUMMOND 1961 MC GUGAN AND RAPSON 1961 GREEN 1962		NORTH WESTERN ALBERTA MAC AULEY 1958 HALBERTSMA 1959 HALBERTSMA AND STAPLIN 1960	
PERMIAN					ROCKY MTN. GROUP	ISHBEL FM.		ROCKY MOUNTAIN FM.		BELLOY FM.
PENNSYLVANIAN						KANANASKIS FM.				TAYLOR FLAT FM.
						TUNNEL MTN. FM.				
MISSISSIPPIAN	CHESTERIAN				RUNDLE GROUP	ETHERINGTON FM.			FLORAL GP.	KISKATINAW FM.
										GOLATA FM.
	MERAMECIAN	POPLAR BEDS	RUNDLE GROUP	MOUNT HEAD FM.		MOUNT HEAD FM.	RUNDLE GROUP	MOUNT HEAD FM.		DEBOLT FM.
	OSAGEAN	RATCLIFFE BEDS		TURNER VALLEY FM.		LIVINGSTONE FM.		TURNER VALLEY FM.		
		MIDALE BEDS		SHUNDA FM.*	BANFF FM.	UPPER MBR.		SHUNDA FM.		SHUNDA FM.
		FROBISHER-ALIDA BEDS ?		PEKISKO FM.		MIDDLE MBR		PEKISKO FM.		PEKISKO FM.
	KINDERHOOKIAN	TILSTON BEDS		BANFF FM.		LOWER MBR.		BANFF FM.		BANFF FM.
		SOURIS VALLEY BEDS								
MISSISSIPPIAN OR DEVONIAN		BAKKEN FM.		EXSHAW FM.		EXSHAW FM.		EXSHAW FM.		EXSHAW FM.

TABLE I.

(1960), Mountjoy (1960,1961), Drummond (1961), McKay (1961), and Green (1962).

The type section of the Banff Formation on Mount Rundle (Kindle, 1924) consists of a 1500-foot sequence divisible into three principal lithologies which are, in ascending order as follows: 1. calcareous shale, 2. interbedded shale and limestone, 3. argillaceous limestone (Nelson, 1961). A fourfold division in the plains region east of Banff is apparent. Here the Pekisko and Shunda Formations, and the lowest part of the Turner Valley Formation are time equivalents to the upper middle and upper subdivisions of the type Banff Formation. The term "plains" Banff Formation is used for that portion of the Mississippian System below the Pekisko Formation and above the Devonian or Mississippian Exshaw Shale in the plains of southern Alberta. In the Thornton Creek section only the upper 120 feet of a total of about 625 feet of Banff equivalent (in the sense of Brown, 1952) was studied. Interbedded dolostones and crinoidal limestones are the main lithologies of the formation in this area.

The Pekisko Formation was originally defined as those 440 feet of strata which overlie the Banff Formation and underlie the Shunda Formation in the Mount Head area (Douglas, 1953). The lithology is mainly coarsely crinoidal limestone in the lower part and very finely crystalline in the upper part. Two hundred and twenty feet of thick-bedded, resistant, light grey, coarse-grained crinoidal limestone, and argillaceous and microcrystalline calcitic dolostones comprise the Pekisko Formation in the Thornton Creek section.

The type Shunda Formation was described by Stearn (1956) as 238 feet of argillaceous dolostone (see Penner, 1958) overlain and underlain conformably by the Turner Valley and Pekisko Formations in Box Canyon near Nordegg. Two hundred and seventy feet of recessive, light to dark grey, argillaceous dolostones and limestones make up the Shunda Formation in the Thornton Creek section.

Douglas (1953) designated the Anglo-Canadian et al Devonian Test well in the Turner Valley field as the type location of the Turner Valley Formation. The 360 feet of beds consist of medium to coarsely crystalline dolostone containing an intermediate unit of finely crystalline carbonates; the formation is conformably overlain and underlain by the Mount Head and Shunda Formations. The Turner Valley Formation is 292 feet thick in the Thornton Creek section and is made of very finely crystalline dolostone and cryptocrystalline limestone.

The Mount Head Formation has its type location in the Mount Head area (Douglas, 1953). Fossiliferous dark-coloured limestone, shaly limestone, and calcareous shale are the main lithologies in the 600 foot sequence, which is overlain conformably by the Etherington Formation. Microcrystalline and argillaceous dolostone comprise the main portion of the 428 feet of Mount Head Formation in the Thornton Creek section. There is considerable controversy concerning correlations of Mount Head and Turner Valley Formations into the Jasper area (see Nelson, 1962).

The Etherington and Tunnel Mountain Formations of Upper Mississippian and Lower Pennsylvanian age are truncated progressively or not deposited northward from the Banff area, and

are both absent in the Thornton Creek section where the Permian Rocky Mountain Formation overlies the Mount Head Formation. The Etherington Formation grades laterally into the Tunnel Mountain Formation to the north of the Banff area (Nelson, 1962).

PERMIAN SYSTEM

The Rocky Mountain Group in the Banff area is divided into three formations (McGugan and Rapson, 1961). In ascending order these are the following: 1. the Upper Mississippian to Lower Pennsylvanian Tunnel Mountain Formation consisting of dolomitic siltstones and sandstones, 2. the Middle Pennsylvanian Kananaskis Formation of silty dolostones and chert, 3. the Permian Ishbel Formation made up of quartzitic siltstones and chert. Each formation within the Rocky Mountain Group has unconformable upper and lower boundary relationships, with the exception of the Tunnel Mountain-Etherington boundary, which is probably conformable. Siliceous sediments disconformably overlying the Mount Head Formation in the Thornton Creek section are called the Rocky Mountain Formation, on the basis of stratigraphic position and gross lithology, and are assigned to the Permian. They amount to 220 feet of thick-bedded spicular chert and light-brown weathering sandstone, and are overlain disconformably in turn by siltstones and sandstones of the Triassic Sulphur Mountain Formation.

PETROGRAPHIC CLASSIFICATION

GENERAL STATEMENT

Folk (1959) recognized that limestones respond to the physical depositional environment in much the same way that terrigenous sediments do; on this basis he produced a simple classification of limestones that is both genetic and descriptive. The classification has 11 basic rock type composed of the following main constituents:

1. allochemical constituents
2. microcrystalline calcite ooze
3. sparry calcite cement.

Allochemical constituents, including intraclasts, bioclasts, pellets and oolites, provide the structural framework; microcrystalline calcite ooze and sparry calcite cement are interstitial material which Folk groups as orthochemical constituents. These constituents combined with texture provide a basis upon which depositional environment may be deciphered.

Varying energy levels produce deposits characteristic of each level. Currents and waves of sufficient strength to winnow microcrystalline calcite ooze, a normal precipitate formed within the basin of accumulation, produce pore space into which sparry calcite cement may be precipitated. Calcite ooze may become the matrix among allochemical constituents provided the hydraulic energy is insufficient for its removal.

Folk's classification is the basis for the one used by the writer, who agrees that the inherent genetic aspects appear sound.

NEW NOMENCLATURE

Folk's classification is becoming widely accepted by workers in carbonate rocks. However, numerous investigators including Illing (1954), Moretti (1957), Beales (1958), Banerjee (1959), Carozzi (1960), Andrichuk (1961), Kent (1961), and Peterson (1962), to name but a few, have found that the silt-sized calcareous equivalent of the siliceous siltstone may be recognized in both recent and ancient carbonate rocks. Modifications of Folk's classification proposed herein stem from the recognition of the intermediate silt grade as a size entity.

Calcisiltite is defined as a limestone composed of grain sizes between 3.9 and 62.5 microns formed by mechanical processes and/or precipitation of silt-sized calcite ooze. Silt-sized calcite grains may be formed by the following methods:

1. comminution of larger bioclasts and faecal pellets.
2. production of silt-sized faecal pellets and bioclasts.
3. comminution of non-skeletal grains including oolites and intraclasts.
4. production of intraclasts and oolites by aggregation processes.
5. precipitation of silt-sized calcite ooze.

Silt-sized calcite grains often form matrix. In such cases terminology similar to that used by Folk for microcrystalline calcite ooze may be used. The following table of terminology for limestones containing silt-sized framework grains and matrix is proposed by the writer. The terms are easily incorporated into Folk's classification as shown in Fig. 3. Intracalcisiltite,

CLASSIFICATION OF CARBONATE ROCKS

				Limestone and Partly Dolomitized Limestone										Replacement and Primary Dolostone			
				> 10% Allochems			< 10% Allochems										
								1 - 10% Allochems		< 1% Allochems			Undisturbed Bioherms		Allochem Ghosts	No Allochem Ghosts	Primary Dolomite
Volumetric Allochemical Composition				Silt-size Calcite < Spar Cement > Ooze	Spar Cement < Silt-size Calcite > Ooze	Spar Cement < Ooze > Silt-size Calcite	Most Abundant Allochem	Silt-size Calcite > Ooze	Ooze > Silt-size Calcite	Silt-size Calcite > Ooze		Ooze > Silt-size Calcite		Evident Allochem			
> 25% Intraclasts				Intrasparite	Intrasiltite	Intramicrite		Intraclast-bearing Calcisiltite	Intraclast-bearing Micrite	Intracalcisiltite	Calcisiltite	Micrite and Dismicrite	Biolithite		Intraclastic Dolostone	Dolostone	Dolomicrite
< 25% Intraclasts	> 25% Oolites			Oosparite	Oosiltite	Oomicrite		Oolite-bearing Calcisiltite	Oolite-bearing Micrite	Oocalcisiltite					Oolitic Dolostone		
	< 25% Oolites	Volume Ratio of Bioclasts to Pellets	3:1	Biosparite	Biosiltite	Biomicrite		Fossiliferous Calcisiltite	Fossiliferous Micrite	Biocalcisiltite					Biogenic Dolostone		
			1:3 - 3:1	Biopelsparite	Pelsiltite	Biopelmicrite		Pellet-bearing Calcisiltite	Pelletiferous Micrite	Pelcalcisiltite					Pelletoid Dolostone		
			1:3	Pelsparite		Pelmicrite											

(modified after Folk 1959)

biocalcisiltite, oocalcisiltite and pelcalcisiltite were coined by Kent (1961) but were used with different quantitative limits.

Table 2 Proposed Nomenclature

SIZE DISTRIBUTION	TYPE OF SILT	ROCK TYPE
< 1% sand-sized allochems; silt-sized calcite framework	any	calcisiltite
	bioclasts	biocalcisiltite
	intraclasts	intracalcisiltite
	oolites	oocalcisiltite
	pellets	pelcalcisiltite
1-10% sand-sized allochems; silt-sized calcite matrix	bioclasts	bioclast-bearing calcisiltite
	intraclasts	intraclast-bearing calcisiltite
	oolites	oolite-bearing calcisiltite
	pellets	pellet-bearing calcisiltite
> 10% sand-sized allochems; silt-sized calcite matrix	bioclasts	biosiltite
	intraclasts	intrasiltite
	oolites	oosiltite
	pellets	pelsiltite

Calcisiltite would represent a higher energy current deposit than would micrite and slightly lesser energy than calcarenite. Illing (1954, p. 16) finds calcilutite (includes calcisiltite) of quantitative insignificance on the open unprotected parts of the Bahama Banks. He believed most silt-sized grains were comminuted sand grains. Calcisiltite could also represent a shallow, protected environment into which silt-sized grains were

precipitated, similar to that described by Banerjee (1959, p. 382).

Dolostone is used as the rock name for those carbonate rocks in which the mineral dolomite predominates (Shrock, 1948). Folk's rock type dolomicrite, the primary dolostone, is a separate class of dolostone in the classification adopted. Cayeux's (1935) classification of calcite-dolomite mixtures has been adopted (Fig. 4).

TEXTURAL TERMS

The Wentworth size grade scale was used for both mechanical and authigenic textures (Fig. 5). Grain size was determined by the aid of a micrometer eyepiece. Size sorting was evaluated in the manner of Payne (1942) who suggested a threefold classification as follows:

1. Good: 90% of the sediment is concentrated in 1 or 2 size classes.
2. Fair: 90% of the sediment if distributed through 3 or 4 size classes.
3. Poor: 90% of the sediment is distributed through 5 or more size classes.

Roundness was determined by visual comparison with Powers' roundness scale. Organic fragments generally have roundness and shape which are influenced by growth, and are intrabasinal in origin; hence these textures may have limited value in this type of study. However, corrasion, solution activity, and denticulation provide valuable information as to what may have happened to a particle before and after burial.

Appositional fabric is either isotropic, if the long axes have a random orientation, or anisotropic if the long axes show

preferred orientation in the aggregate. Fabric becomes difficult to determine as grains approach equidimensional shapes. A pseudo-anisotropic fabric may be developed by differential pressure solution as present in sample TC 16. The samples showed a predominance of isotropic fabric.

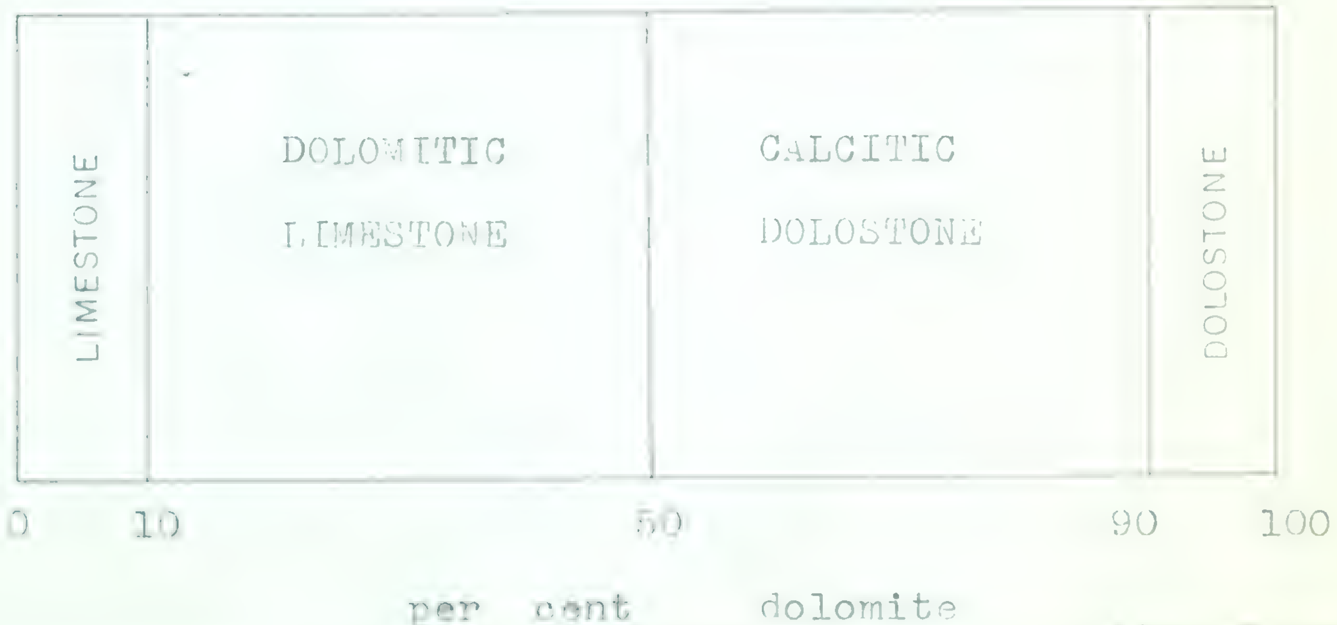
Packing was determined as dense, moderate or loose by qualitative visual estimation. Poor and moderate packing was characteristic of most samples.

Pore space was described as intergranular, intercrystalline, fracture or fossiliferous porosity.

GRAIN SIZE CLASSIFICATION

SIZE		NOMENCLATURE	
Millimeters	Microns	Mechanical Texture	Authigenic Texture
		very coarse pebble	extremely coarse crystalline
64			
		coarse pebble	
16			
		medium pebble	
4			
		fine pebble	
2			
		very coarse sand	very coarse crystalline
1	1000		
		coarse sand	coarse crystalline
1/2	500		
		medium sand	medium crystalline
1/4	250		
		fine sand	fine crystalline
1/8	125		
		very fine sand	very fine crystalline
1/16	62.5		
		coarse silt	coarse microcrystalline
1/32	31		
		medium silt	medium microcrystalline
1/64	15.6		
		fine silt	fine microcrystalline
1/128	7.8		
		very fine silt	very fine microcrystalline
1/256	3.9		
		ooze	cryptocrystalline

CLASSIFICATION OF CALCITE-DOLOMITE MIXTURES



after Cayeux (1935)

Fig. 2

DESCRIPTION OF CONSTITUENTS

Allochemical Constituents

Allochemical constituents include intraclasts, oolites, pellets, and bioclasts, all of intrabasinal origin. Intraclasts are intrabasinal calcareous rock fragments formed by erosional, aggregational and recrystallization processes. Beales (1958, 1961) has drawn attention to "homeomorphic" grains which look alike but have diverse origins. Highly agitated environments are capable of ripping semiconsolidated sediments off the sea floor, the fragments of which are then resedimented after a period of reworking. An important contributor to Bahamian sands are grains formed by aggregational processes (Illing, 1954). He noted that aragonite grains and aggregate grains of cemented silt-sized detrital skeletal material became cryptocrystalline by recrystallization, producing clastic grains with no primary structure. The intraclasts encountered in the present study are spherical to irregularly rounded homogeneous bodies of light to dark grey-brown cryptocrystalline calcite. Material comprising intraclasts is often identical to that of the matrix, but may contain earlier deposited materials such as bioclasts, smaller intraclasts and detrital quartz in addition to authigenic constituents such as dolomite rhombohedra and quartz. Intraclasts

are present in which algae and foraminifera have been recrystallized to near obliteration, producing grains of dark cryptocrystalline calcite. Beales (1956, p. 862) and Illing (1954, p. 19) have noted a similar recrystallization phenomonon.

Oolites are characterized by an original concentric structure. Most commonly oolite growth takes place more by a combination of aragonite needle agglutination and abrasion phenomena rather than by direct precipitation over rolling nuclei according to Carozzi (1960, p. 239). Two types of oolites were encountered in the present study. One type is comprised of a light microcrystalline calcite nucleus with a darker laminated calcite rim, the diameter of the oolite generally being about 0.1 mm. A second and larger type has both concentric and radial structure; the material comprising the oolite which averages about 0.9 mm. diameter. Radial texture is known to be of diagenetic origin. The smaller type of oolite is believed to have been carried in suspension for it forms only minor parts of the rock. Sample TC 11 has oolites with dark penetrations in the periphery attributed to algal borings. Beales (1958, p. 1848) noted similar phenomena in oolites of the Ordovician Black River Group. Superficial oolites have a single coating over the nucleus and represent the earlier stages of oolitization. They generally have a larger diameter than normal oolites which tend to develop in modal sizes only.

Pellets are aggregate bodies produced as animal excrement. Benthonic scavengers such as gastropods, worms, pelecypods, and crustaceans consume mud which may be excreted with rather diagnostic features. Considerable variation exists as to the pre-

valence, origin, size and shapes of faecal pellets. Amstutz (1958) reviews pertinent literature pertaining to faecal pellets besides describing specimens from southern Washington. Characteristic features include diameters greater than 0.03 mm.; spherical, ovate, elongate and irregularly rounded shapes; pitted, striated, and smooth surfaces; "curly" internal structure or no internal structure; compositional differences from other constituents; and chitonous, calcareous, and siliceous fragment inclusions. Pellets are generally rich in organic matter; most are friable when fresh and are held together by mucous and algae. Characteristic of intertidal to shallow marine environments, pellets are preserved in waters having very low velocity currents and waves, along with conditions leading to hardening by dessication or by bacteriological precipitation of aragonite; lack of scavengers may also be important.

Folk (1959) classifies all fossil and fossil fragments other than those which grew _in situ_ as bioclasts. Fossils and fossil debris are important indicators of depositional environment in addition to being the most frequent framework constituents. Crinoids, bryozoans, algae, echinoids, brachiopods, gastropods, ostracods, sponge spicules, foraminifera, corals and calcispheres were encountered, but only crinoids, bryozoans, foraminifera, algae and brachiopods were of rock nomenclatural significance.

Crinoid columnals and calyx plates are the most common framework material. They are composed of single crystals of calcite, and, as such, have unit extinctions between crossed nicols. The characteristic perforations of plates, and cellular structure of columnals is often preserved. Crinoid skeletons have a porous

structure which becomes filled with clear secondary calcite cement. Axial canals of columnals and original pore spore surrounding crinoidal debris is also filled with clear calcite cement. The peripheries of some columnals contain dark cryptocrystalline calcite which filled rotted or dissolved portions as the columnal was rolled on a mud bottom. The debris is generally abraded and denticulated; strained and pentagonal-shaped columnals are uncommon, as were attached columnals.

Well-preserved echinoid spines are present with arrangements of septa and interseptal tissue which form distinctive and varied patterns.

Fronds and stemlike colonies of bryozoans are common in varying degrees of preservation and fragmentation. The double-walled rounded chambers have distinctive colonial arrangements. Spines are present on some walls, some of which are pyritized.

Algae are present in mamillated, encrusting, tubelike and stalked forms. Dark cryptocrystalline calcite with irregular laminae of light crystalline calcite characterize the mamillated and encrusting forms, some of which are partly recrystallized. Tubular forms have a core of clear microcrystalline calcite surrounded by dark cryptocrystalline calcite. There is a possibility that these are of worm origin. Stalked forms are characterized by clear microcrystalline calcite walls with dark microcrystalline calcite filling radial perforations and center portions.

Brachiopod shells have a fibrous undulating or non-dulating habit with the fibres paralleling the shell surface; some have,

in addition, a thin outer prismatic layer; puntae are uncommon. These shells tend to have a larger size than the other bioclasts, hence were fragmented and extensively abraded.

Gastropods are high-spired forms in which the original light brown fibrous shell is generally recrystallized and commonly dissolved on exterior portions. Chambers were filled with cement, allochems and matrix.

The calcite fibres comprising ostracod carapaces are oriented normal to the shell surface. Carapaces have distinctive ovate and elongate shapes and hinge and free margin structures.

Calcispheres are small spherical bodies of unknown origin, attributed to the genus Calcisphera by Williamson (1880). They are characterized by nucleus of clear microcrystalline calcite surrounded by a dark cryptocrystalline calcite wall of variable structure. Wall structures include radial transections, coronas, laminae and homogeneous layering. Possible origins that have been suggested for calcispheres include tests of protozoans, vegetal reproductive capsules, various algal structures, siliceous and calcareous microfossils and inorganic origin.

Foraminifera are present as both planispiral and rectilinear types. Planispiral endothyrid types have a dark cryptocrystalline calcite wall and chambers filled with calcite cement or matrix. Occasionally endothyrids formed nuclei around which calcite mud became compacted, the microfossil showing various stages of recrystallization. Rectilinear non-endothyrid foraminifera are both septate and non-septate. The walls of these forms are composed of light and dark microcrystalline calcite, and the chambers are generally filled with matrix. It is possible that some objects

identified as non-septate foraminifera could be brachiopod spines, which may be hollow or solid.

Sponge spicules are present in some chert nodules. Most spicules, only the monaxonic types were noted, tend to be "resorbed" or difficult to separate distinctly from the encompassing silica matrix.

Orthochemical Constituents

Interstitial materials are most commonly comprised of microcrystalline calcite ooze and/or sparry calcite cement. Folk (1959) termed these orthochemical constituents. Calcite ooze, a common constituent, is defined as calcite grains less than 3.9 microns in diameter. Characteristically it has a turbid brown-grey color. Folk considered it to form mainly by chemical or biochemical precipitation in sea water and only in minor quantities by comminution of allochems. The writer believes that abrasion dust, which is genetically different, may reach significant proportions occasionally, but, nevertheless it is classified as calcite ooze since it cannot be differentiated petrographically. Calcite ooze may be the main constituent of a rock, depending upon the degree to which it is diluted by allochems and terrigenous constituents. Calcite cement precipitates in original pore space and as such may be responsible for a complete loss of primary porosity. Cement is distinguished from calcite ooze by its clarity and coarser crystal size, which in these rocks ranges from microcrystalline to very coarsely crystalline. Two generations of cement is evident in some cases. An uneven thin layer of prismatic crystals normal to shells and other grain surfaces was observed to be deposited before the main portion

of the pores was filled with calcite anhedra.

OTHER CONSTITUENTS

Clay minerals, detrital and authigenic quartz, chert and pyrite are the most important non-carbonate constituents. Brown-grey clay minerals are the most dominant and persistent terrigenous materials, occurring as discrete laminae or disseminations within the matrix. Detrital quartz, mainly of silt-size, is also a minor terrigenous constituent; clear grains, both strained and unstrained predominate. Most have a high degree of angularity owing to corrosion, and small grain size, for increase in angularity generally accompanies decrease in grain size. Authigenic quartz subhedra and euhedra of silt-size replace allochems and matrix. Overgrowths on detrital quartz also produce better-defined crystal shapes. Chert composed of microgranular quartz occurs as nodules and disseminations. Pyrite in all stages of alteration to limonite and hematite, is an ubiqutous constituent; a finely disseminated and/or framboidal texture is common; nodules and replacement occurrences are rarer. It also forms nuclei of dolomite rhombohedra.

Minor non-carbonate constituents include collophane, detrital potash feldspar and plagioclase feldspars, tourmaline, mica, glauconite and carbonaceous organic material.

Seventy-three samples from the Thornton Creek section were digested in 10 to 50 per cent hydrochloric acid to determine the type and amount of insoluble residue. Very-light to dark-brown-grey mud was the most persistent residue. Light to dark grey chert, a single occurrence of green chert from the Mount Head Formation, silt-sized quartz, pyrite and organic material were

also identified.

Procedure, pertinent data and detailed descriptions of the residues are given in Appendix C. The weight percentage of residue in vertical profile is plotted in Fig. 7 . Terms used to describe residues are those used by Ireland (1958), a prominent worker in this field.

MINERAL COMPOSITION

CALCITE-DOLOMITE RATIOS

Percentages of dolomite in 75 samples from the Thornton Creek section were determined by X-ray diffraction techniques, following the procedures outlined by Weber and Smith (1960). A standard calcite-dolomite calibration curve (Fig. 6) was prepared from a series of known mixtures of the Iceland Spar variety of calcite and coarsely crystalline dolomite, both of which were identified by diffraction prior to construction of the curve. A linear relationship of

$$y = 99.25x + 2.65$$

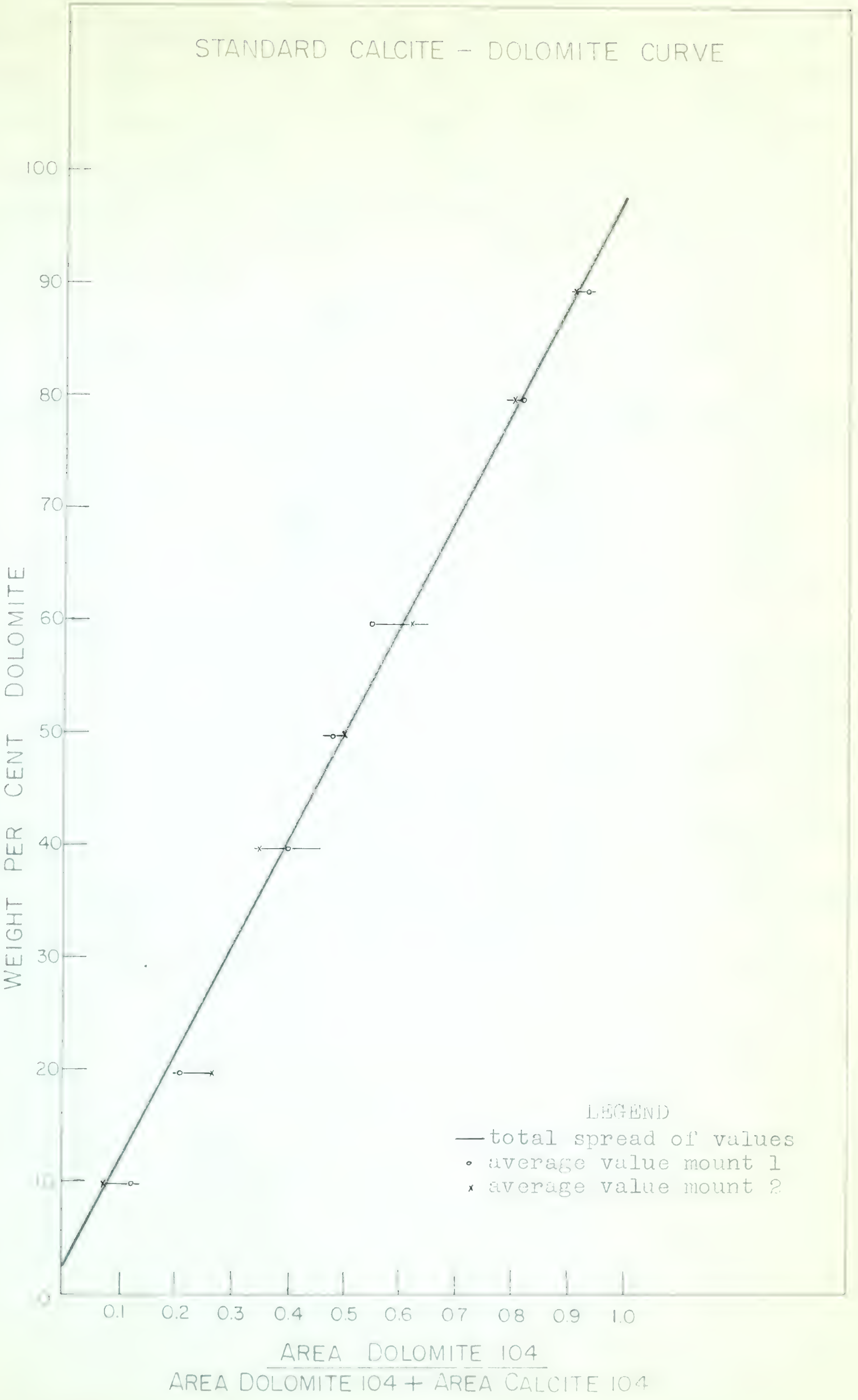
where x is the area under the dolomite 104 peak over the sum of the areas under the dolomite 104 and calcite 104 peaks, and y is the weight per cent dolomite in the known mixtures. The relationship is in approximate agreement with that obtained by Weber and Smith. The weight per cent dolomite was read directly off from a graph of the standard curve, and is plotted on Fig. 7. The detailed procedure and pertinent data are outlined in Appendix D.

CLAY MINERAL ANALYSIS

Six selected insoluble clay residues were identified from X-ray diffraction powder patterns. The clay was suspended in water in a beaker and allowed to settle and dry on a glass slide.

The only clay mineral identified was illite with its characteristic 10Å basal spacing and subsequent integral series of 00ℓ reflections. Glycolation of two of the samples verified the presence of only a non-expandable clay mineral. MacEwan (1950) and Peterson (1962) state dioctahedral micas (including illite)

Fig. 6


STANDARD CALCITE – DOLOMITE CURVE
WEIGHT PER CENT DOLOMITE
100
90
80
70
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
AREA DOLOMITE 104
AREA DOLOMITE 104 + AREA CALCITE 104
LEGEND
— total spread of values
∘ average value mount 1
x average value mount 2

have d_{060} between 1.49 and 1.52Å. Extrapolation of d_{020} gave values of d_{060} within or below this range, indicating that the illite is dioctahedral. It is suspected that any acid soluble chloritic type minerals may have been destroyed during acidization (see Peterson, 1962). The X-ray results are summarized in Table 3.

TABLE 3

Tabulation of Clay Mineral Identifications

Sample Number	Lithology	Identification	d_{060}
TC 51	dolostone	illite*	1.48
TC 43	dolostone	illite	1.49
TC 33-17	micrite	illite	1.49
TC 26	dolostone	illite	1.48
TC 19	dolostone	illite*	1.49
TC 4	biomicrite	illite	1.49

* indicates glycolated sample

The identications of this study are in agreement with Weaver (1958a, 1958b), who stated that illite is generally the dominant clay mineral in limestones and dolostones and that most of the Palaeozoic illites in limestones are the dioctahedral type. Weaver (1958a) also considered them to be detrital in origin and derived from muscovite or illite in the source area.

ROCK TYPES OF THE THORNTON CREEK SECTION

GENERAL STATEMENT

Fourteen rock types are recognized in the Thornton Creek section, the dolostones being divided into two types. The distribution of the rock types is shown in Table 4, and photomicrographs of typical examples are shown in Plates I and II. The uppermost Banff Formation is comprised mainly of dolostone and biomicrite; both lithologies are believed to be of very shallow-water origin. The Pekisko rocks contain a high bioclast content; hence the lithologies are predominantly biomicrite and biosparite; dolostones are common. The Shunda Formation is composed of relatively large quantities of ooze admixed with bioclasts and intraclasts. Dolostone and micrite make up the rocks of the Turner Valley Formation whereas dolostone is the predominant lithology of the Mount Head Formation. Chert and sandstone are the rock types of the Rocky Mountain Formation.

TABLE 4

Sample Distribution by Rock Types in the Thornton Creek Section

	Banff Fm.	Pekisko Fm.	Shunda Fm.	Turner Valley Fm.	Mount Head Fm.	Rocky Mtn. Fm.	Total
micrite			6	2			8
biomicrite	4	6	4		1		15
intramicrite			5				5
oomicrite			1				1
biosiltite		1					1
biomicrudite		1					1
biosparite	1	4					5
intrasparite		1	2				3
oosparite	1						1
dolostone	7	5	3	4	11		30
mudstone	1						1
sandstone						1	1
conglomerate						1	1
chert						1	1

DESCRIPTION AND INTERPRETATION OF ROCK TYPES

Dolostone--Type A

Appearance in thin section; fine-microcrystalline to fine-crystalline dolomite rhombohedra and a high terrigenous content characterize this rock type. Irregular laminae rich in clay minerals, quartz and dolomite are common. Calcite is mainly ooze; bioclasts, when present include crinoids, brachiopods, algae, foraminifera and calcispheres. Chert in a few samples preserves some traces of spicules and crinoids. Pyrite may be locally concentrated or disseminated.

Interpretation: type A dolostones are characteristic of the Banff, Pekisko and Shunda Formations. The paucity of bioclasts, high terrigenous and high dolomite contents and relationships with overlying and underlying strata suggest that this rock type is formed in shallow, restricted environments. Walpole and Carozzi (1961) outlined five microfacies which they considered to represent a general environmental time and bathymetric sequence for the Rundle Group in west central Alberta. Type A dolostone is similar in description to that microfacies considered by these authors to have formed in the greatest relative depth of water. The present writer's conclusion concerning the genesis of this rock type is, therefore, at variance with that of Walpole and Carozzi. The abundance of terrigenous material may be interpreted as, 1. representing uplift or proximity of source causing a more rapid influx of detritus, 2. change of conditions in the depositional basin suppressing chemical activity to the extent that terrigenous materials accumulated by default (Folk,

1959, p. 20). A land-locked lagoon or effectively barred basin and high temperatures necessary to produce evaporation possibly coupled with restricted inflow of waters bearing calcium carbonate, might produce these conditions. These rocks classify as littoral evaporite--lagoonal or intertidal formed magnesium-rich sedimentary rocks according to the geographical classification of dolostone formation given by Fairbridge (1957, p. 133). Figure 7 demonstrates the close relationship between dolomite and insoluble residue content in type A dolostone.

Most of the Mississippian rocks of southern Alberta and Saskatchewan represent a broad, often shallow, epicontinental sea (Edie, 1958; Illing, 1959; Thomas and Glaister, 1960). Such a regional setting also appears applicable in the Jasper area. Lang (1947, p. 47) reports that anhydrite occurs through most of the lower Rundle Formation in the Jasper No. 1 well at Folding Mountain, near the eastern boundary of Jasper National Park. This attests to the fact that salinities at times were very high and waters were very shallow. Frequent preservation of laminae suggests few burrowing organisms were present in the fairly saline environments. Some laminae pinch and swell rapidly and they are not uniformly spaced vertically.

Dolostone--Type B

Appearance in thin section: finely microcrystalline to finely crystalline dolomite has a granoblastic or patchy texture commonly containing two distinct crystal sizes. Calcite content is of relict brachiopods, bryozoans, criniods, and some traces of ooze. Terrigenous material includes disseminated clay minerals and traces of detrital quartz. Chert and pyrite are often present.

Interpretation: Type B dolostones are characteristic of the Turner Valley and Mount Head Formations. The relict structures indicate the original limestone contained bioclasts which might have made up high percentages of some of these rocks. A more detailed description is given under Dolomitization.

Biomicrite

Appearance in thin section: crinoids, bryozoans, algae, brachiopods, and foraminifera are distributed in an ooze matrix. Subordinate contributions come from other bioclasts; intraclasts and oolites are not common. All degrees of fragmentation of bioclasts may be noted but most are disarticulate and somewhat abraded. Clay mineral content is variable and detrital quartz is present in a few samples. Pyrite is ubiquitous, both disseminated in the matrix and replacing bioclasts. Most samples tend to have isotropic fabric and poor sorting.

Interpretation: the presence of ooze, poor sorting and isotropic texture suggest a poorly agitated environment. Fine sediment accumulation takes place where there is shelter from currents in either shallow or deep water. Folk interprets fossils comprising biomicrites as being sedentary, or else waves and currents were calm or impersistent in the depositional area, and the ooze was not winnowed out. Scavenging organisms effectively reduce particle size and this could possibly have brought about some of the fragmentation of particles (Dapples, 1938; Ginsburg, 1957). Some allochems were subjected to bottom traction as indicated by abraded and fragmented shells. It is suggested that some grains are not indigenous to the environment in which they accumulated, although the exact amount cannot be stated

unequivocally. Oolites are believed to have been transported into an area favorable for their preservation. Chambers of bryozoans and ostracods have both ooze and cement filling; this suggests some were indigenous and not tossed about extensively before deposition, whereas others were highly agitated. Some ooze could have been formed from algal secretions, comminuted fossil debris, and disintegration (Lowenstam, 1955), but most was probably precipitated.

Douglas (1958) noted that rapid lateral and vertical lithofacies changes take place in Mississippian rocks in the Mount Head area. Differences in intensity and persistence of waves and currents together with differences in physiography of the depositional area in a predominantly shallow water environment are believed responsible for some of the lithofacies changes encountered. Even a lagoon or sheltered area with bottom irregularities may have yielded sediments containing different proportions of framework and matrix.

Biosparite

Appearance in thin section: this rock type is predominantly composed of bioclasts cemented with clear calcite. Crinoidal debris predominates with the remainder comprised of bryozoans, algae, echinoids, brachiopods, gastropods and ostracods. Intraclasts and oolites are also common. Clay minerals and detrital quartz are characteristically present in minor amounts and ooze may be present interstitially, in cavities or in axial canals of columnals. Dolomite is minor or absent and preferentially replaces matrix and intraclasts, distinct from cement. Biosparites have good to fair sorting with isotropic fabric and

usually moderate packing.

Interpretation: a highly agitated environment is responsible for winnowing out most of the ooze, which remains only as fillings in rotted portions of columnals, cavities of gastropods and bryozoans, and as minor amounts trapped interstitially between grains. The comparatively low clay mineral content is indicative of a high energy current environment in which clay minerals were winnowed out with the ooze. Environments which may give rise to this rock type are in areas swept by vigorous currents, and these are mostly near shore or in very shallow water above wave base. The high bioclast content shows that this rock type forms mainly in open marine environments.

Some of the fossils are of ecologic significance but the majority inhabit many different settings. Existing stalked crinoids occupy depths from five fathoms to abyssal, although the majority are very shallow-water dwelling. They tend to live in local "gardens" but are spread over a wide geographic range, and upon death are very susceptible to fragmentation. Calcareous algae, when abundant, generally indicate water less than 100 feet deep. Illing (1954, p. 17) found algae made up an average of 39 per cent of the sands on the margin of the Bahama platform in contrast to only 1 per cent on the shelf lagoons. The depth of water at the outer edge of the platfrom is about 60 feet, a depth which Johnson (1961, p. 23) claims is the lower limit of at least half of the species of algae. He claims the most luxuriant developments occur at shallow depths where wave action is not strong, but where there is good circulation of water. Completely crustose forms are limited mainly to quiet water; irregular thick

crusts occur in depths from tide level to about 30 feet as do stalked forms or dasyclads. Calcispheres were found by Baxter (1960) in calcarenites and calcilutites of the Mississippian Salem Limestone of Illinois. Beales (1958, p. 1857) reports calcispheres from the Rundle Group of southern Alberta. Calcispheres were found by the writer in lithofacies containing abundant ooze, which in this area are characteristic of the Shunda Formation. The writer found no conclusive evidence as to their origin.

Oosparite

Appearance in thin section: oolites, including superficial oolites, lithified by calcite cement constitute oosparites. The well-sorted oolites are admixed with crinoidal débris, foraminifera, ostracods, bryozoans, echinoids and intraclasts. Calcite cement is preferentially replaced by dolomite.

Interpretation: the lack of ooze matrix and low clay mineral content support present day evidence that oolites are forming in very shallow water, highly agitated environments saturated with calcium carbonate. Newell and Rigby (1957) noted that oolites and skeletal materials tend to be selectively separated by waves and currents in shoal areas of vigorous flow, but both became swamped by pellets, skeletal material, and mud in grassy, less agitated areas.

Mudstone

Appearance in thin section: laminae alternately rich in quartz and clay minerals are mixed with a few bioclasts. Quartz, both strained and unstrained, predominates. Dolomite is more commonly associated with clay minerals.

Interpretation: more rapid accumulation of terrigenous materials than calcareous sediments took place. A restricted environment with increased salinity is suggested by the lack of bioclasts. Soft-sediment folding took place after several superimposed laminae had been deposited. Contemporaneous deposition and folding is attributed to a gravitational force directed down the slope, which, according to Pettijohn (1957, p. 598) may be as low as 1.5 to 3 degrees and still allow mass flowage to take place. Walpole and Carozzi (1961, p. 1845) reported an east to west increase in bathymetry for portions of the Rundle Group in west central Alberta but no absolute amount was stated.

Biosiltite

Appearance in thin section: a high crinoid content with a matrix of comminuted bioclastic debris and calcite of silt size makes up most of this rock. Ooze fills crinoid columnal axial canals; otherwise it is replaced by dolomite, which occurs in minor percentages. Minor amounts of intraclasts, clay minerals, and quartz are present. The sorting is poor, packing is moderate and fabric is isotropic.

Interpretation: the lack of ooze indicates an environment in which it could be winnowed out. Precipitation of silt-sized calcite and its accumulation with comminuted bioclasts in a protected environment is indicated.

Intrasparite

Appearance in thin section: greater than 25 per cent intraclasts cemented together with calcite cement defines intrasparite. Varying amounts of bioclasts include crinoids, brachiopods, algae, bryozoans, foraminifera, calcispheres and ostracods. Dolomite

rhombohedra are confined to trapped interstitial matrix. Oolites are present in a few samples, terrigenous material is confined to the intraclasts. Fair to poor sorting, isotropic fabric and moderate to loose packing are the textural features of intrasparites.

Interpretation: intrasparites are formed in highly agitated environments which have strong or persistent currents of sufficient strength to winnow ooze and produce intrabasinal rock fragments. Most of the ooze was winnowed out, providing pore space into which subsequent cement was precipitated.

Biomicrudite

Appearance in thin section: particulate constituents with a greater average diameter than two millimeters bound with an ooze matrix is required. The rudaceous constituents are articulate brachiopods and encrusting algae in this rock type. Bryozoans, crinoids, echinoids, foraminifera and intraclasts are subordinate and of smaller size. A considerable clay mineral component is present in the ooze. The framework is poorly sorted, loosely packed and has isotropic fabric.

Interpretation: this rock is a shallow, moderately quiet water deposit for much interstitial ooze remains and algae are present. The fine-pebble size of the brachiopods results from their articulate nature.

Micrite

Appearance in thin section: allochem constituents make up less than 10 per cent, the bulk of the rock being ooze. Crinoids, foraminifera, ostracods, calcispheres, brachiopods, and gastropods make up the bioclasts. Bryozoans and oolites are

absent, but intraclasts are present. Clay mineral content varies and only a few grains of detrital quartz are present. Dolomitization occurs both in patches and disseminations.

Interpretation: micrites accumulate in weakly or impersistently agitated, deep or shallow waters. Shallow-water lagoonal or protected water deposits similar to those presently accumulating on the Bahama Banks is believed to be the mode of origin of the micrites in this study. The ooze is probably physicochemically precipitated from waters supersaturated with calcium carbonate. Bio-chemical precipitation is considered to have been less important.

Intramicrite

Appearance in thin section: intraclasts with interstitial ooze make up this rock type. Minor amounts of crinoids, calcispheres, brachiopods, gastropods, foraminifera and ostracods occur. Clay minerals are disseminated. Textural features include poor to good sorting, isotropic fabric and loose packing.

Interpretation: this rock type is probably transitional between areas of predominant ooze and predominant intraclasts. Folk (1959) interprets intramicrites as being formed when intraclasts are washed into poorly agitated environments containing much ooze.

Oomicrite

Appearance in thin section: oolites, commonly mixed with intraclasts, in an ooze matrix and some cement. Clay minerals occur in minor amounts. The texture is poorly sorted and loosely packed with an isotropic fabric.

Interpretation: Folk (1959) considers this a rare rock

type formed when oolites are washed into a low energy depositional site containing much ooze. This lithology is probably transitional between areas containing abundant oolites and much ooze. The lack of bioclasts may be an indication of above normal salinities.

Conglomerate

Appearance in thin section: phenoclasts of poorly sorted chert pebbles (containing sponge spicules, microgranular quartz and chalcedony), detrital quartz, and sandstone rock fragments occur in a matrix of brown cryptocrystalline phosphatic material.

Interpretation: this rock is a basal conglomerate laid down by the Permian transgressing sea after a considerable depositional hiatus.

Chert

Appearance in thin section: abundant relict spicules are preserved as nearly colorless microcrystalline to cryptocrystalline quartz.

Interpretation: a thick accumulation of sponge spicules in a quiet, shallow-water environment. Much of the silica is redistributed.

Sandstone

Appearance in thin section: well sorted, clear quartz grains are mixed with a few grains of phosphatic material.

Interpretation: a highly agitated environment is responsible for these well-sorted sandstones.

DEPOSITIONAL HISTORY OF THE THORNTON CREEK SECTION

Mississippian rocks in western Canada are a highly complex series of carbonate rocks that reflect the widespread shallow-

water shoal, bank, and lagoonal environments in which they accumulated. Fluctuations of sea level periodically resulted in restricted environments with their characteristic sediments, which grade laterally and vertically into sediments formed typically under normal open marine conditions (Douglas, 1958; Illing, 1959; Thomas and Glaister, 1960).

Such a regional pictrue fits the rapid cyclic changes of environments reflected in the uppermost Banff Formation sediments accumulating in the Jasper area. The lowest rocks examined are biosparite, representing a very shallow, normal marine environment as determined by the lack of ooze and the presence of algae. These sediments pass upward into predominantly ooze laid down in a protected zone with a decreased amount of life. The protected environment possibly became restricted during the deposition of the mudstone in unit 3 which was entirely unfavorable for organisms, and argillaceous sediments accumulated by default. A period of normal marine water followed, which was very shallow as shown by the biomicrite lithology containing an abundance of algae, but soon became restricted as manifested by the dolostone of unit 5. Biomicrite of unit 6 represents another refreshing by normal sea waters. The area soon again became a restricted basin or lagoon in which the sediments of unit 7 were dolomitized. Brachiopods and current bedding at the base of unit 8 indicate open marine conditions favorable for the existence of a benthonic fauna. A restricted environment followed and this continued through unit 9, reaching a climax in unit 10, which is completely dolomitized. The overlying oosparite represents an agitated environment, which is also shown by the presence of current bedding. Unit 12

represents the last restriction to exist during the deposition of the Banff Formation. Brown (1952) reports current bedding from this latter widespread unit.

The beginning of Pekisko time in the Jasper area marked a return to open marine conditions which persisted for an extended length of time. Thick accumulations of crinoidal debris took place, and algae at the base of the formation indicate that the depth of water during the early period of marine inflow probably did not exceed 40 feet. The depositional site gradually became sheltered, for unwinnowed ooze matrix increases upwards from the base. Dolostone at the top of unit 13 represents a restricted environment with a paucity of life. Another restriction occurred during the deposition of sediments about 22 feet above the base of unit 14 after a period of sedimentation probably in a protected area. Biomicrite indicates a sheltered environment 32 feet above the base of unit 14; this gave way to open circulation. Dolostone of unit 15 is evidence of another restriction of the waters. Shallow, protected water deposition probably took place in unit 16, followed by open sea circulation in the basal portion of unit 17 represented by biosparite. Thirteen feet from the base of unit 17 protected deposits became dolomitized, and the unit ended with conditions in which brachiopods flourished. A highly agitated environment in which intraclasts were formed is represented by intrasparite of unit 18. Pekisko time ends with a restricted sea in which argillaceous sediments accumulated by default, and ooze became dolomitized; this lithofacies is barren of organic remains.

Shunda time in the Jasper area is marked by a prolific production of calcite ooze and a reduced benthonic fauna; conditions

very much like those existing today on the Bahama Banks must have existed. Mixing of intraclasts and oolites with ooze still further simulate Bahama Bank conditions. From the base of the formation to the first restricted environment in unit 26, the lithologies represent protected water accumulations. Following this, micrite is overlain by intrasparite, a highly agitated deposit, in unit 28. A restricted environment culminates in unit 29 after a period in which biomicrite accumulated. Micrite of unit 31 occurs between the mixed intraclast and ooze deposits of unit 30 and the oolites and ooze of unit 32. Unit 33 manifests the oncoming of restriction again; intramicrite at the base grades upward into micrite, a true protected bank deposit with a lack of organisms. The unit ends with a restricted environment, which is represented by an argillaceous dolostone lithofacies. Thus ended Shunda deposition.

Turner Valley sedimentation began with a renewed connection to the open sea; micrites were formed on bank conditions. The sedimentary record from this point is not clear because of obliteration by dolomitization, but restricted environments are recognized at 135, 155 and 210 feet from the base of the formation. This suggests conditions not unlike those existing in Pekisko time because Mountjoy (1961, p. 40) records abundant fossil debris from equivalent strata on Mount Greenock.

Dolomitization has largely obscured the depositional history of the original sediments of the Mount Head Formation. Corals in units 42 and 45 indicate well-lighted, aerated waters. This suggests that open shelf conditions existed at this time. Relict crinoids, bryozoans, and brachiopods are also present throughout some of the formation. However, Moore, (1958, p. 154) reports

anhydrite occurs in the Mount Head Formation immediately east of the Jasper Park boundary in Superior et al Solomon Creek No. 1 well. This indicates evaporitic conditions were attained in more easterly regions during Mount Head time.

A basal conglomerate represents the beginning of Permian deposition following a period of erosion. McGugan and Rapson (1961) consider the massive chert is a replacement of carbonates that took place following a period of exposure and before deposition of the overlying sandstone, which marks a second marine transgression. Cressman (1955, p. 25) concluded that the bedded cherts of the Permian Phosphoria Formation in Montana resulted from "...the accumulation and partial diagenetic reorganization of sponge spicules and other siliceous organic remains, and the facies relationship between sandstone and chert probably resulted from the sorting of the siliceous organic remains form the quartz sand and the subsequent accumulation of the organic silica on the basinward side of the sand." A similar situation possibly existed in the Thornton Creek area, with the overlying well-sorted sandstone lithology indicating a regressing of the seas.

DIAGENESIS AND SUBSEQUENT ALTERATION

Diagenesis, as here used, is defined as the chemical and physical changes that sediments undergo during and after their accumulation, but before lithification takes place. Description as a temporal sequence is not possible since some of the changes that take place are overlapping in time and may have different stages of development, hence, processes are considered separately.

Dolomitization

All dolomite is secondary, and two types, A and B, are recognized with porphyroblastic and mosaic textures respectively. It is not known whether the origins of these types are different.

Type A dolostone displays porphyroblastic texture, is frequently laminated, and generally contains a relatively high terrigenous content. It is characteristic of the Banff, Pekisko, and Shunda Formations, and is cyclically interbedded with limestones in these formations. The origin of dolostones in an interbedded limestone and dolostone sequence may be explained by seepage refluxion (Adams and Rhodes, 1960). If a restricted body of ocean water is allowed to evaporate, brines with increased magnesium concentration will settle in the lowest depressions available and will permeate down through the underlying sediments. This provides an active mechanism by which magnesium may be transported and distributed to form dolomite (see Bissell and Chilinger, 1958). Peterson (1962) has shown that if the chemical composition of a sediment is determined in part by salinity variations caused by evaporitic concentration of normal sea water, the sediment may undergo a mineral paragenesis which results in a magnesium-rich mineral assemblage. Seepage refluxion is believed to be responsible for the formation of type A dolostone. Dolomitization "fronts" in some of these rocks provide evidence that magnesium-bearing solutions passed through them. Pyrite frequently forms the nucleus of dolomite rhombohedra, and since pyrite forms in reducing conditions below the sediment interface, the surrounding dolomite was probably formed under similar conditions.

Type B dolostone displays mosaic texture, and is common in the Turner Valley and Mount Head Formations. It is very finely crystalline to coarsely microcrystalline, contains relict bioclasts, and is generally thickly bedded and less resistant than the predominantly limestone formations. Two distinct crystal sizes are often noted, possibly being a result of a textural control inherent in the original limestone; dolomite rhombohedra replacing ooze matrix are noted to be finer crystalline than rhombohedra replacing bioclasts. The occurrence of iron-stained rims is evidence that the dolomite contains considerable iron in the lattice; this evidence is also supported by the weathering shades of greys, browns, and yellows.

Silicification

Redistributed silica occurs throughout the Thornton Creek section. Most silica is present as chert nodules, but some is present as overgrowths on detrital quartz. Some chert is pore filling; some is distributed in fracture veins, which suggests distribution during or following the Rocky Mountain orogeny; some has silicified bioclasts preserving original structures. Silt-sized authigenic quartz euhedra and subhedra are common in rocks containing ooze, suggesting siliceous sponges may have flourished in the quiet water environments. Some chert nodules contain rhombohedral outlines that are filled with chert, showing that carbonate was leached before a second stage of silicification. Trapped rhombohedra are evidence that silicification occurred later than dolomitization in some of these rocks, whereas Illing (1959) has shown that silicification (believed to be penecontemperaneous with sedimentation) preceded

dolomitization in the Turner Valley Formation at Moose Mountain.

Siliceous sponge spicules, witnessed by relict structures, is the probable source of silica. A mechanism of chertification is suggested that is similar to that proposed by Lowenstam (1942), who found that chert nodules may form in the host rock by dissolved siliceous skeletal material moving laterally to envelope undissolved spicules.

Cementation

Sparry calcite cement, an important lithifying agent, is precipitated in original pore space formed after winnowing of ooze, and in cavities of fossils. The cement is probably derived from interstitial solutions contained at the time of burial, and from solution of shell fragments after burial. Moving solutions saturated with calcium carbonate would presumably travel in paths of least resistance, this being through originally permeable sediments, and under favorable conditions precipitate calcite in them. Geopetal accumulation of mechanically deposited grains in pore spaces was followed by two stages of cementation. The earlier stage is a layer of prismatic calcite coating the cavity; the later stage fills the remainder of the internal cavity. This situation is analogous to that described by Sander (1951, p. 171).

Sparry calcite cement of this study is not recrystallized ooze because: (1) no relict structures are present, (2) it occurs as structurally continuous overgrowths on crinoid columnals, (3) no rocks containing widely spaced allochem occurences are cemented by clear calcite, and (4) cement has sharp boundaries with grains and no transections of allochems by clear calcite takes place; in addition, there are no continuous gradations of crystal sizes

from cement into ooze.

Recrystallization

Recognizable recrystallization phenomena are negligible in this study. Some algae and gastropod shells were recrystallized, and a few occurrences of recrystallized calcite surrounding grains, representing an aureole of recrystallization, were present.

Pyritization

Pyrite forms an ubiquitous constituent of most lithofacies containing ooze. Pyrite forms in reducing conditions just under the sediment-water interface (Moretti, 1957; Banerjee, 1959). Hydrogen released from organic matter attacked by anaerobic bacteria combines with sulphur to produce hydrogen sulphide. Pyrite is formed when hydrogen sulphide combines with iron.

Solution

Solution denticulates some bioclasts and has dissolved the exterior portions of some gastropod shells. Some porosity is developed by solution of bioclast relicts in the Mount Head Formation. A stylolite is a surface marked by mutual interpenetration of the two sides, generally thought to be the result of pressure-solution phenomena taking place in lithified rock. Since most stylolites in this study could only be observed under the microscope, they are termed microstylolites. Insoluble constituents such as clay minerals are often concentrated along these surfaces which parallel the bedding mainly. The microstylolites are a few millimeters in length, occur in both fine and coarse carbonates, and have relief in the order of a few millimeters only. Numerous examples of pressure-solution welding of framework particles occur.

Compaction

Compaction due to the weight of overlying sediments greatly reduces original pore space among sedimentary particles besides resulting in a forced migration of a portion of the contained fluids. The process contributes greatly to lithification. Compaction is manifested by the presence of brachiopod and ostracod shells crushed in situ. Pore space, now filled with calcite cement, often had shapes preferentially elongated parallel to the bedding plane. This appears to be a result of compaction.

Biotic Activity

Benthonic organisms are capable of overturning sediments and destroying primary structural features in addition to passing materials through their digestive systems. Scavengers such as worms, crustaceans, echinoids, molluscs, and holothurians are capable of producing textural features which include aggregation of particles, particle-size reduction, erosion, and mixing of sediments, besides such structural features as the formation of mounds, tubes and burrows (Ginsburg, 1958, p. 81). Holothurians appear especially capable of mascerating larger grains (Johnson, 1951, p. 83). Modifications by organisms is often penecontemporaneous with deposition.

Veining

Post-lithification fractures filled with calcite, dolomite and some chert are believed to have formed during the Rocky Mountain orogeny. The fracture veins are subparallel, and of short length and narrow width generally. Microstylolites and framework constituents are cut by these fracture veins.

SUMMARY AND CONCLUSIONS

The study of a 1500-foot section of some Upper Palaeozoic sedimentary rocks located near the headwaters of Thornton Creek in Jasper National Park was undertaken to reconstruct the sedimentation, and to investigate the diagenesis and alteration of these rocks.

Epicontinental seas during Mississippian time in western Canada allowed the accumulation of relatively shallow water carbonate rocks which may be classified following a scheme slightly modified from Folk (1959).

Depositional environments have been interpreted from textural, mineralogic, gross faunal and stratigraphic information. The sediments reflect the degree of agitation in shallow-water shoal, intershoal, bank, and lagoon environments. The sedimentation was found to be cyclical.

Uppermost Banff time in the Jasper area was one of rapid fluctuations of sea level which resulted in the alternation of very shallow-water, normal marine sediments and dolostones formed in restricted environments.

Pekisko time in the Jasper area was marked by shoal environment in which crinoid life abounded. The depth of water in early Pekisko time was probably not greater than 30 to 40 feet.

The Shunda Formation is characterized by an abundance of ooze. An environment with a decreased amount of life, similar to that present on the Bahama Banks today, is envisaged.

The sedimentary record of the Turner Valley Formation is largely obliterated by dolomitization but conditions of deposition similar to those existing during Pekisko time is suggested.

The Mount Head Formation is largely dolostone but relict fossils suggest shoal conditions existed during a portion of its time.

A basal conglomerate was laid down by a transgressing Permian sea following a period of erosion. Relief of about five feet occurs along the Mississippian-Permian contact at Thornton Creek.

The lowest Permian beds in this area consist of a thickly bedded spicular chert representing a shallow-water environment. Well-sorted sandstone overlies the chert, and probably ends Upper Palaeozoic deposition.

The processes of diagenesis overlap in time. Dolomitization is the predominant diagenetic change; the rocks are otherwise relatively unaltered. Dolomitization probably took place at an early diagenetic stage, and may be the result of magnesium-rich solutions caused by evaporitic concentration of normal sea water in restricted environments.

Illite was the only clay mineral identified in six random samples of limestone distributed through the section, and is probably detrital in origin, being derived from muscovite and illite in the source area.

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APPENDIX A

FIELD DESCRIPTION OF THE THORNTON CREEK SECTION

The Thornton Creek section was measured up section with the aid of a Brunton compass and 100-foot tape. A litholog of the profile is shown in Figure 7. Intraformational units were each assigned a number and were sampled in most cases; covered intervals were not assigned numbers. In some cases additional samples were selected within units. These samples are labelled with a "b", an additional number, or a "u" if the sample was taken from the basal portion, a measured distance from the base, or from the upper portion respectively. Additional samples chosen without reference to position in units are labelled with an "A" or "B". "TC" indicates Thornton Creek. Height above base refers to height above the base of the section.

Intraformational units were differentiated on differences detected in the field. Criteria upon which field units were chosen include changes in gross lithology, crystallinity, bedding, color and weathering profile; and the presence of chert, argillaceous material and fossils.

The section may be located on Geological Survey of Canada Map 41-1961 (Mount Robson southeast).

Unit	Description	Thickness feet	Height above base ft.
	Overlying beds--Triassic Sulphur Mountain Formation. Contact not exposed.		
	ROCKY MOUNTAIN FORMATION		
54	SANDSTONE; quartzose, very fine grained, light brown weathers light brown. Some chert at the base.	25	1522-1547
53	CHERT; light grey weathers very light grey, very resistent, massive. At 50' from base some lenses of sandstone, light brown, medium grained, quartzose. Above 98' some sandstone lenses.	192	1331-1522
52	CONGLOMERATE; dark grey. Chert pebbles and fragments up to 3" long.	1	1330-1331
	Total thickness Rocky Mountain Formation 217'. Contact with Mount Head Formation is disconformable. Relief at contact is about 5'.		
	RUNDLE GROUP		
	MOUNT HEAD FORMATION		
51	DOLOSTONE; argillaceous, coarsely microcrystalline, light brownish yellow weathers light greyish yellow, recessive. Chert in lower 20'. Bedding from 6" to 2' thick.	97	1233-1330
50	DOLOSTONE; coarsely microcrystalline, light yellowish grey weathers same, recessive, thickly bedded. White chert in irregular small nodules.	43	1190-1233
49	DOLOSTONE; finely crystalline, very light grey weathers light grey, porous. Solitary corals and traces of crinoid fragments. From 40' to 46' above base chert nodules and lenses parallel to the bedding.	77	1113-1190
48	DOLOSTONE; finely microcrystalline, argillaceous, light grey weathers light yellow, recessive. Bedding is less than 1' thick. Upper 2' contain abundant grey chert.	13	1100-1113

Unit	Description	Thickness feet	Height above base ft.
47	DOLOSTONE; very finely crystalline, light brownish grey. Contains abundant irregular nodules of dark grey chert but upper 20' is without chert. Traces of vivid green chert.	58	1042-1100
46	DOLOSTONE; coarsely microcrystalline, light grey weathers light brownish grey. Moderately resistant, beds from 2' to 4' thick. Traces of white calcite specks.	18	1024-1042
	COVER; probably dolostone.	29	995-1024
45	DOLOSTONE; medium microcrystalline, light grey weathers light brownish grey. Silicified cup corals and some traces of brachiopods.	6	989-995
44	DOLOSTONE; coarsely microcrystalline, light grey weathers very light yellow, recessive. Argillaceous, traces of laminae. Some bryozoans and white calcite specks. Bedding from 3" to 1' thick.	12	977-989
43	DOLOSTONE; argillaceous, very finely crystalline, light yellow grey weathers light yellow grey to light yellow. Abundant crinoid calyxes. Porosity result of leached fossil fragments.	6	971-977
42	DOLOSTONE; argillaceous, very finely crystalline, light grey. Common crinoid fragments and other fossil debris particularly in upper 10'. Some large colonial corals and a few large solitary corals. Bedding greater than 2' thick. Forms upper part of cliff-forming units 40, 41 and 42.	30	941-971
41	DOLOSTONE; calcitic, coarsely microcrystalline, light grey weathers same, resistant. White crystalline calcite specks up to 1/2" long. Some beds with crinoids and traces of bryozoans. Bedding from 1' to 3' thick.	14	927-941

Unit	Description	Thickness feet	Height above base ft.
40	LIMESTONE; dolomitic, coarse grained, light brownish grey weathers light grey. Bedding from 2' to 10' thick. Abundant crinoid debris.	25	902-927

Total thickness Mount Head Fromation 428'.
Contact conformable.

TURNER VALLEY FORMATION

39	DOLOSTONE; calcitic, argillaceous, light grey, coarsely microcrystalline. Occasional vug up to 4" diameter. At 49' recessive gulley. 1 or 2 beds of argillaceous dolostone. Some white crystalline calcite fracture veins.	132	770-902
	DOLOSTONE; argillaceous, light grey. Traces of laminae and thin dolomitic shale interbeds.	4	766-770
38	DOLOSTONE; very fine crystalline, light brown weathers light grey brown. Porous in part. Traces of white calcite specks. Slightly recessive, bedding greater than 2' thick. At 45' above base 2' of dolostone, argillaceous, light yellow, recessive.	64	702-766
37	LIMESTONE; dolomitized, cryptocrystalline, light to medium grey weathers light grey. Traces of fine laminae. Resistant, bedding greater than 3' thick. Traces of crinoid fragments.	22	680-702
36	DOLOSTONE; very finely crystalline, light brown weathers light grey brown. Traces of crinoid debris. Some vugs up to 1'x 3', some leached fossils. Resistant, bedding is greater than 3'.	39	641-680
35	DOLOSTONE; very finely crystalline, very light grey weathers light brownish grey. Trace of pin-point porosity and some vugs.	13	628-641

Unit	Description	Thickness feet	Height above base ft.
34	LIMESTONE; dolomitzed, cryptocrystalline, light grey weathers same. Resistant, vuggy in part of basal 3'. Grades up into dolomite, microcrystalline to finely crystalline, pin-point porosity.	18	610-628
Total thickness Turner Valley Formation 292'.			
SHUNDA FORMATION			
33	LIMESTONE; light to medium grey. Basal dolomitized limestone with argillaceous limestone interbeds grades upward into dolomitized cryptocrystalline limestone. At the top 5' of argillaceous dolostone, weathers brownish grey, platey splitting, finely laminated, recessive, traces of brachiopods.	23	587-610
32	LIMESTONE; medium grey weathers light grey, oolitic, coarse grained. Bedding from 1' - 3' thick.	11	576-587
31	LIMESTONE; cryptocrystalline, light grey weathers same. Trace of calcite specks. Bedding from 1' to 4' thick.	22	554-576
COVER		1	553-554
30	LIMESTONE; argillaceous, dolomitized, calcarenitic, medium grained, light to medium grey weathers light grey. Some white calcite eyes and specks near the top.	44	509-553
29	LIMESTONE; argillaceous, dolomitized, medium grained. Medium grey brown weathers light grey brown. In part crinoidal. Bedding from 1' to 2' thick recessive, partly covered. Upper 1' is dolostone, argillaceous.	11	498-509
28	LIMESTONE; calcarenitic, medium to coarse grained, medium to dark grey weathers medium brownish grey, resistant unit. Clear calcite specks near base; traces of porosity, and some black chert in upper half. Occasional solitary coral and traces of crinoid fragments.	42	456-498

Unit	Description	Thickness feet	Height above base ft.
27	LIMESTONE; dolomitized, cryptocrystalline, light grey weathers same. Resistant bedding 1' to 5' thick. Traces of laminae and vugs.	12	444-456
26	DOLOSTONE; calcitic, argillaceous, fine microcrystalline, light yellow grey, recessive.	1	443-444
25	LIMESTONE; dolomitized, calcarenitic, very coarsely grained, light yellow grey weathers same. Bedding 2' thick.	4	439-443
24	LIMESTONE; very fine calcarenite in basal 5' has some calcite eyes. Grades into limestone, dolomitized, cryptocrystalline.	15	424-439
23	LIMESTONE; dolomitized, cryptocrystalline, light grey weathers same. Solitary cup coral noted near top. Forms resistant cliff, bedding greater than 2' thick.	23	401-424
22	LIMESTONE; dolomitized, very fine grained. Weathers recessive, partly covered.	5	396-401
21	LIMESTONE; calcarenitic, light brownish grey weathers light grey. Traces of limonitic and hematitic specks, some calcite eyes, and traces of porosity. Partly recessive, bedding from 4" to 2' thick.	29	367-396
20	LIMESTONE; calcarenitic, very fine to coarse grained, light to medium grey weathers light brownish grey. Moderately resistant, bedding 1' to 3' thick.	28	339-367

Total thickness Shunda Formation 271 feet.

PEKISKO FORMATION

Unit	Description	Thickness feet	Height above base ft.
19	DOLOSTONE; calcitic, argillaceous, medium microcrystalline, dark grey weathers light grey brown. Recessive, splits platey in 1/2" partings and less.	10	329-339
18	LIMESTONE; dolomitized, calcarenitic, very fine to coarse grained, medium to dark grey weathers light brownish grey. Scattered 1/2" eyes of white crystalline calcite. Trace of brachiopods. Bedding from 4" to 1' thick.	8	321-329

Unit	Description	Thickness feet	Height above base ft.
17	LIMESTONE; calcarenitic, crinoidal with abundant brachiopods in basal 4', dark grey weathers medium grey. Recessive, bedding from 2" to 1' thick. At 13' above base limestone, argillaceous, dolomitized, dark grey. Contains abundant brachiopods. Very recessive. At top 6" limestone, argillaceous, contains abundant brachiopods with internal cavities lined with drusy calcite.	22	299-321
16	LIMESTONE; calcarenitic, fine grained, light to dark grey weathers light grey. Some solitary corals. Scattered chert lensss. Resistant, basal 5' recessive essentially one bed.	40	259-299
15	DOLOSTONE; calcitic, argillaceous, light grey weathers brownish grey. Moderately recessive, bedding 1" thick and less. Small 1" diameter nodules of chert, dark grey, near top. Scattered 1" diameter solitary corals and colonial corals noted in basal 5'. A few vugs filled with white calcite.	14	245-259
14	LIMESTONE AND DOLOSTONE, interbedded. LIMESTONE; dolomitized to non-dolomitized, argillaceous in part, calcarenitic, coarsely to very coarsely grained, medium grey weathers light grey. Nodules of chert up to 1" thick parallel to the bedding, chert ends 30' from base. Part of same massive cliff as unit 13 but is thinner bedded, and slightly more resistant than units 13 and 15. DOLOSTONE; coarse microcrystalline, calcitic. Located at top of unit. Isolated eyes of white crystalline calcite.	55	190-245
13	LIMESTONE; coarse grained, light grey weathers same. Massive, resistant, cliff-forming unit, partings 2' to 10' thick. Crinoidal debris abundant. Isolated eyes of crystalline white calcite.	71	119-190

Total thickness Pekisko Formation 220'.
Total thickness Rundle Group 1210'.

Unit	Description	Thickness feet	Height above base ft.
BANFF FORMATION			
12	DOLOSTONE; argillaceous, very finely crystalline, medium grey weathers same. Finely laminated, bedding from 1" to 1'. Forms a recessive 2' to 5' gulley.	5	114-119
11	LIMESTONE; dolomitized, calcarenitic, medium grey weathers light grey to brownish grey. Some layers contain abundant brachiopods at base. Traces of laminae and crossbedding. Essentially one thick unit with partings 1' to 5' thick, resistant cliff forming.	26	88-114
10	DOLOSTONE; argillaceous, coarsely microcrystalline, medium brownish grey. Bedding about 1' thick.	5	83-88
9	DOLOSTONE; finely crystalline, light grey weathers same. Finely laminated, bedding from 2" to 1'. Traces of stylolites.	18	65-83
8	LIMESTONE and DOLOSTONE. LIMESTONE; dolomitized, calcarenitic, very coarse grained. Brachiopods at base. Weathers medium grey. Traces of laminae and crossbedding.	6	59-65
	DOLOSTONE; calcitic, argillaceous.		
7	DOLOSTONE; argillaceous, coarse microcrystalline, medium grey weathers light yellow grey. Traces of laminae which weather red. Bedding from 1" to 1' thick.	8	51-59
6	LIMESTONE; argillaceous, dolomitized, calcarenitic, medium grey weathers light yellow grey. Common brachiopods.	1	50-51
5	DOLOSTONE; calcitic, argillaceous, silty medium microcrystalline, dark grey weathers medium brownish grey to light yellow grey. Bedding from 3" to 8" thick with partings 1" and less, traces of fine laminae.	10	40-50

Unit	Description	Thickness feet	Height above base ft.
4	LIMESTONE; medium grained, calcarenitic, weathers light brownish grey. Some thin argillaceous lenses and interbeds, partings 6" to 1' thick. Moderately resistant. Traces of brachiopods.	6	34-40
3	MUDSTONE; silty, dolomitized, brown weathers dark brown. Finely laminated, partings 1/4" and less. Recessive.	2	32-34
2	LIMESTONE and DOLOSTONE, interbedded. LIMESTONE; argillaceous, calcarenitic, medium grained, medium grey. Occurs in lenses and bands 1" to 4" thick. Traces of brachiopods. DOLOSTONE; argillaceous, brown weathers light yellow brown. Bedding 2" to 6" thick, splits in pieces 1/4" thick.	27	5-32
1	LIMESTONE; calcarenitic, medium grained, medium to dark brown weathers light to medium brownish grey. Partings 6" to 1' thick. Traces of brachiopods.	5	0-5

Total Banff Formation measured 119'.

APPENDIX B

SELECTED THIN SECTION DESCRIPTIONS

Thin section number: TC 1

Formation: Banff

Height above base of section in feet: 0 - 5

Petrographic Description

Composition of carbonate by X-ray determination:

93% calcite

7% dolomite

Constituents:

64% Bioclasts:

53% Crinoids: fragmented, abraded, denticulated columnals and calyx plates. Dark calcite ooze fills axial canals and peripheral boundaries of columnals. Common cellular structure. Fragments average 0.46 mm. diameter.

2% Bryozoans: fragmented. Light-coloured walls, some dark calcite walls. Dark calcite ooze fills chambers.

5% Algae: mostly tubular forms with dark microcrystalline calcite walls. Interiors filled with clear and slightly coarser microcrystalline calcite and some authigenic quartz. Some well-preserved stalked forms.

1% Echinoids: poorly preserved spines average 0.46 mm. diameter. Authigenic quartz in axial canal.

1% Brachiopods: fragmented fibrous calcite shells with a layer of secondary prismatic calcite normal to the shell surface. Some non-fibrous shells.

1% Gastropods: thin fibrous light-brown calcite shells. Chambers filled with calcite ooze, bioclasts, and clear microcrystalline calcite.

1% Ostracods: articulate and disarticulate forms. Interior cavities filled with cryptocrystalline to very fine-crystalline calcite.

<1% Calcisphere: single occurrence. Light-coloured cryptocrystalline to microcrystalline calcite nucleus with a darker laminated wall 0.026 mm. thick. Faint radial limes transect wall in one sector. Clear outer thin calcite cover over dark laminae. Diameter 0.143 mm.

4% Intraclasts: Spherical to irregular shapes of dark brown cryptocrystalline calcite, locally grading to microcrystalline calcite. Inclusions of bioclasts, dolomite rhombohedra, and subhedral authigenic quartz. Diameter varies from 0.08 to 0.61 mm.

<1% Oolites: Microcrystalline calcite nucleus with a darker microcrystalline calcite laminated rim; or a rim of material identical to nucleus separated by a thin clear calcite band. Diameter averages 0.12 mm.

21% Interstitial material:

17% Cement: clear sparry calcite fills original pore space. In optical continuity with crinoidal debris.

2% Matrix: dark brown calcite ooze among bioclasts. Calcite composing matrix identical to that composing intraclasts.

2% Porosity: intergranular.

4% Terrigenous material:

4% Clay minerals.

Texture:

Size: medium sand.

Sorting: poor.

Roundness and shape: very angular to subrounded, elongate.

Fabric: isotropic.

Packing: moderate.

Microstructure: pressure-solution welding of some grains. Microstylolites have short length.

Alteration:

7% Replacement:

7% Dolomite: dolomite euhedra maximum diameter 0.117 mm., diameter averages 0.080 mm. Interstitial material and intraclasts selectively replaced.

Special features:
Possible algal origin, in part, for intraclasts suggested by weak laminae.
Gastropod shells dissolved in part.

Classification: medium-grained crinoidal biosparite.

Thin section number: TC 2

Formation: Banff

Height above base of section in feet: 5 - 32

Petrographic Description

Composition of carbonate by X-ray determination:

92% calcite

8% dolomite

Constituents:

12% Bioclasts:

4% Bryozoans: well-preserved light brown fibrous calcite shells, sacklike chambers filled with microcrystalline clear calcite. Some pyritized walls. Average diameter 0.240 mm.

1% Echinoids: well-preserved spines average 0.12 mm. diameter.

<1% Ostracods: a mosaic of clear microcrystalline calcite fills interior cavities. Thin exterior layer of secondary prismatic calcite normal to articulate carapaces. 0.37 mm. across.

4% Crinoids: rounded and pentagonal columnals. Sharp to denticulated boundaries generally abraded. Canals filled with calcite matrix. Average diameter 0134 mm.

3% Algae: patches of dark microcrystalline calcite in the form of irregular tube-like fragments.

<1% Oolites:
Single occurrence. Diameter 0.34 mm. Nucleus partly of dolomite subhedra, remainder of microcrystalline calcite with a trace of chert. A ring of 0.004 mm. thick secondary calcite coats the oolite, the crystals normal to the surface.

19% Terrigenous material:

2% Quartz: detrital. Angular to very angular shapes with corroded grain boundaries. Diameter averages 0.03 mm.

17% Clay minerals: brown grey. Occur in matrix.

59% Interstitial material:

59% Matrix: about 48% calcite ooze and 11% comminuted fossil debris of silt size.

Cement: clear microcrystalline calcite cement in original pore space, mainly fossil chambers, about 3%.

Texture:

Size: medium sand.

Sorting: poor.

Microstructure: incipient microstylolites and poor laminae developed. Differential pressure solution welding at bioclast contacts.

Alteration:

10% Replacement:

8% Dolomite: euhedra occur in matrix. Average diameter 0.02 mm.

1% Chert: microgranular quartz. Contains inclusions. Patchy distribution.

1% Pyrite: framboidal texture, disseminated. Altered to hematite.

Special features:

Rare elongate collophane grains denticulated by dolomite euhedra. A single grain of green tourmaline present. Tubelike fragments consisting of patches of microcrystalline calcite of probable algal or worm origin. Some partly replaced by chert and partly recrystallized.

Classification: medium-grained argillaceous bryozoan-crinoidal biomicrite.

Thin section number: TC 3

Formation: Banff

Height above base of section in feet: 32 - 34

Petrographic Description

Composition of carbonate by X-ray determination:

62% dolomite

38% calcite

Constituents:

2% Bioclasts:

Scattered, abraded organic fragments. Single crinoid columnal of 0.48 mm. diameter. Some fibrous brachiopod shells pinch and swell. Pyrite clotted and disseminated in brachiopod shells, some to altered hematite.

73% Terrigenous material:

49% Quartz: detrital. Diameter ranges from 0.02 to 0.13 mm., averages 0.05 mm. Strained and unstrained with uncommon inclusions. Angular to subrounded grains.

24% Clay minerals: medium to dark brown. Associated more commonly with dolomite rhombohedra than with quartz in the clay laminae.

<1% Feldspar: detrital. Rare grains of plagioclase feldspar and microcline.

9% Interstitial materials:

9% Matrix: ooze.

<1% Cement: overgrowths of silica cement on quartz grains.

Texture:

Size: coarse silt.

Roundness and shape: angular to subrounded, equidimensional.

Microstructure: distinct clay mineral and quartz silt laminae. Flow structures reveal soft sediment movement.

Alteration:

16% Replacement:

15% Dolomite: euhedra and subhedra in calcite matrix. Replaces some quartz grains. Uncommon zoning in rhombohedra.

1% Pyrite: framboidal texture, altered to hematite.

Special features:
Rare grains of collophane.
Rare thin plates of a mineral with low to moderate birefringence, probably sericite.
Calcite corroded some quartz grain boundaries.
Redistributed silica in the form of overgrowths. Overgrowths clear but some have inclusions.

Classification: dolomitic mudstone

Thin section number: TC 4

Formation: Banff

Height above base of section in feet: 34 - 40

Petrographic Description

Composition of carbonate by X-ray determination:

92% calcite

8% dolomite

Constituents:

56% Bioclasts:

29% Crinoids: abraded and denticulated fragments.

Average diameter 0.66 mm.

1% Echinoids: maximum diameter 0.40 mm., average diameter 0.14 mm. Well-preserved structures.

20% Algae: encrusting, tubelike and moundlike forms. Inconsistent laminae of medium brown cryptocrystalline and light brown microcrystalline calcite. Some patches of coarser microcrystalline calcite. Diameter of ball shapes ranges from about 4 mm. to 0.2 mm.; the nucleus composed of echinoderm fragments, bryozoans, quartz grains and microcrystalline calcite. Inclusions of 0.03 mm. dolomite euhedra and 0.023 mm. quartz grains occur in laminae. Moundlike forms reach 5.11 mm. in height. Dark cryptocrystalline calcite tubes filled with cryptocrystalline to microcrystalline calcite.

3% Bryozoans: interiors filled with clear microcrystalline calcite cement.

1% Ostracods: microcrystalline calcite commonly fills the interior. Carapaces average 0.05 mm. across.

1% Gastropods: high-spired form. Shells replaced by microcrystalline calcite; chambers filled with brown cryptocrystalline calcite and some subhedral dolomite. Height of shell 2.58 mm.

<1% Calcisphere: clear microcrystalline calcite nucleus with a dark thin calcite rim.

1% Brachiopods: undulating fibrous shell fragments and one long thin curved shell.

1% Oolites: dark laminated rim over clear calcite nuclei.

28% Interstitial material:

28% Matrix: about 20% ooze and 8% silt-sized calcite matrix.

Cement: about 3% clear calcite euhedra occupies chambers of ostracods and gastropods. In part replaced by dolomite.

8% Terrigenous material:

8% Clay minerals: form irregular disturbed partings. Limonitic stained.

<1% Quartz: detrital. Diameter averages 0.03 mm.

Texture:

Size: medium sand.

Sorting: poor.

Roundness and shape: angular to subrounded, elongate.

Packing: loose.

Fabric: isotropic.

Microstructure: microstylolites shown by clay partings and bioclast contacts. A fracture vein of very fine-crystalline calcite crosses part of the slide.

Alteration:

8% Replacement:

8% Dolomite: euhedra averages diameter 0.063 mm. in matrix and chambers of organisms. Strongest development associated with clay minerals.

Special Features:
Grains of collophane uncommon.
Rare calcite inclusions in quartz grains.
Framboidal pyrite scattered, some as inclusions in dolomite rhombohedra.

Classification: medium-grained algal-crinoidal biomicrite

Thin section number: TC 5

Formation: Banff

Height above base of section in feet: 40 - 50

Petrographic Description

Composition of carbonate by X-ray determination:

56% dolomite

44% calcite

Constituents:

44% Terrigenous material:

22% Clay minerals: medium brown. Concentrated in laminae containing fewer quartz grains.

22% Quartz: detrital. Subangular. Secondary quartz with minute rhombohedral inclusions. Diameter averages 0.04 mm., the maximum diameter 0.055 mm.

25% Interstitial material:

25% Matrix: ooze mainly admixed with clay minerals. Rare organic fragments of silt size.

Texture:

Size: medium microcrystalline.

Microstructure: laminae of clay minerals and detrital quartz pinch and swell.

Alteration:

31% Replacement:

31% Dolomite: subhedra and euhedra average 0.025 mm., mainly in clay mineral laminae. Numerous rhombohedra contain rounded pyrite nuclei.

Special features:
Framboidal pyrite disseminated.

Classification: medium- microcrystalline argillaceous silty calcitic dolostone.

Thin section number: TC 6

Formation: Banff

Height above base of section in feet: 50 - 51

Petrographic Description

Composition of carbonate by X-ray determination:

56% calcite

44% dolomite

Constituents:

48% Bioclasts:

47% Crinoids: fragments mainly light brown columnals, some original cellular structure. Average 0.76 mm. diameter.

Denticulated irregular boundaries owing to pressure solution welding and dolomitization. Undulatory twinning suggests strained grains.

1% Bryozoans: sacklike chambers filled with clear cryptocrystalline calcite and occasional dolomite crystal.

<1% Brachiopods: fibrous fragments with undulating irregular appearance.

15% Terrigenous material:

14% Clay minerals: irregularly distributed in matrix, some patchy distribution. Some concentrated at rhombohedra and bioclast boundaries. Light red-brown colour in reflected light.

1% Quartz: mainly detrital. Some redistributed to form chert. Common angular to subangular grains with corroded boundaries. Size ranges from 0.015 to 0.063 mm., diameter average 0.031 mm.

5% Interstitial material:

5% Matrix: patchy ooze largely replaced by dolomite.

<1% Cement: clear crystalline calcite in bryozoan and brachiopod chambers.

Texture:

Size: coarse sand.

Sorting: fair.

Roundness and shape: angular, equidimensional.

Fabric: isotropic.

Microstructure: poorly laminated. Differential pressure-solution welding at grain boundaries.

Alteration:

40% Replacement:

37% Dolomite: uniformly sized 0.023 mm. diameter dolomite subhedra abundant in matrix and common in some bioclasts. About 8% replaces bioclasts along or within boundaries of the grains

and the axial canals of columnals. About 29% replaces interstitial material.

3% Pyrite: disseminated and locally concentrated, partly altered to hematite.

Tr. Chert and collophane: replacing two possible foraminifera.

Special features:

A single 0.128 by 0.359 mm. grain of muscovite.
A single grain of collophane with its boundary denticulated by dolomite rhombohedra.

Classification: coarse-grained argillaceous dolomitized crinoidal biomicrite.

Thin section number: TC 7

Formation: Banff

Height above base of section in feet: 51 - 59

Petrographic Description

Composition of carbonate by X-ray determination:

98% dolomite

2% calcite

Constituents:

35% Terrigenous materials:

33% Clay minerals: medium brown. Discontinuously laminated.

2% Quartz: detrital. Very angular to subangular grains, some strained. Some vacuoles in the grains.

Texture:

Size: coarse microcrystalline.

Alteration:

65% Replacement:

65% Dolomite: secondary subhedra and anhedra, numerous rhombohedra trapped within larger rhombohedra. Diameters range from 0.004 to 0.080 mm.

Special features:

Pyrite partly altered to hematite, irregularly shaped and distributed parallel to the clay laminae. Quartz grains with dolomite subhedra in 1/4 mm. thick discontinuous pockets. Differential pressure-solution welding of adjacent quartz grain contacts. Clay mineral and quartz grain laminae more prominent at one end. A gradation to more poorly laminated portion. Dolomite corroded quartz grain boundaries, causing increase in angularity.

Classification: coarse-microcrystalline argillaceous dolostone.

Thin section number: TC 8A

Formation: Banff

Height above base of section in feet: 59 - 65

Petrographic Description

Composition of carbonate by X-ray determination:

71% dolomite

29% calcite

Constituents:

20% Bioclasts:

20% Crinoids: columnals average 1.02 mm. diameter. A portion of one stem intact. Some columnals have undulatory extinction.

Tr. Bryozoan: poorly preserved debris and brachiopod shells.

30% Terrigenous material:

29% Clay minerals: medium brown. In the interstitial material. Mixed with traces of pyrite, collophane, and chert.

1% Quartz: detrital. Some stained grains. Very angular to subrounded shapes. Size ranges from 0.015 to 0.080 mm., average 0.037 mm. diameter.

Texture:

Size: coarse microcrystalline.

Microstructures: light brown patches with few detrital quartz grains and little clay minerals surrounded with medium brown material with numerous quartz grains and much clay minerals, a result of mixing argillaceous and calcareous laminae. Abundant dolomite rhombohedra in the light coloured patches.

Alteration:

50% Replacement:

50% Dolomite: rhombohedra very abundant interstitial to bioclasts and only replaced them near the grain boundaries or in fractures.

Tr. Chert: small amounts replacing matrix.

Special features:
Rare primary grains of collophane.
Pyrite finely disseminated in clay laminae.
Anisotropic fabric apparent for the long dimensions of the bioclasts parallel the clay mineral laminae.

Classification: coarse-microcrystalline calcitic argillaceous dolostone.

Thin section number: TC 8B

Formation: Banff

Height above base of section in feet: 59 - 65

Petrographic Description

Composition of carbonate by X-ray determination:

50% calcite

50% dolomite

Constituents:

42% Bioclasts:

39% Crinoids: crinoid columnals, average diameter 1.10 mm., maximum diameter 1.90 mm. Grain boundaries partly denticulated by dolomitization and pressure solution welding.

3% Bryozoans: fragments of stems, chambers filled with cryptocrystalline and sparry calcite. Fibrous calcite walls.

<1% Brachiopods: fibrous fragments, long curved shapes.

4% Intraclasts:
Irregularly rounded. Medium-brown-grey cryptocrystalline calcite, contains uncommon quartz with inclusions of calcite. Quartz diameter averages 0.03 mm. Dolomite rhombohedra inclusions. Patches of slightly darker dolomite rhombohedra suggest some intraclasts may be replaced.

8% Terrigenous material:

8% Clay minerals: irregular and patchy distribution. Red-brown in reflected light owing to high pyrite content altering to hematite, some confined to rounded entities resembling dolomitized intraclasts.

Texture:

Size: very coarse sand.

Sorting: well.

Roundness and shape: subrounded, equidimensional.

Fabric: isotropic.

Packing: moderate.

Microstructure: differential pressure-solution welding concentrates clay minerals.

Alteration:

46% Replacement:

46% Dolomite: rhombohedra preferentially replace material interstitial to bioclasts. Numerous intraclasts strongly replaced. About 8% within allochemical constituents. Dolomite subhedra and anhedra average 0.040 mm. diameter. Commonly zoned.

Tr. Quartz and collophane: secondary.

Special features:

Rare oolites, gastropod fragments and disarticulate ostracods.

Pyrite mainly altered to hematite.

Fracturing produces traces of porosity.

Classification: very coarse-grained dolomitized crinoidal biomicrite.

Thin section number: TC 9

Formation: Banff

Height above base of section in feet: 65 - 83

Petrographic Description

Composition of carbonate by X-ray determination:

94% dolomite

6% calcite

Constituents:

<1% Bioclasts:

<1% Crinoids: single columnal partly dolomitized, boundary denticulated owing to dolomitization.

6% Interstitial material:

6% Matrix: ooze.

3% Terrigenous material:

3% Clay minerals: disseminated and in discontinuously streaked distribution. Some hematitic stain from altered pyrite.

Texture:

Size: fine crystalline.

Microstructure: poorly developed laminae as a result of clay mineral distribution.

Alteration:

91% Replacement:

91% Dolomite: subhedra in two distinct sizes, diameters averaging 0.128 mm. and 0.031 mm. Smaller rhombohedral inclusions in

larger rhombohedra, some pyrite inclusions. Zoning of dolomite rhombohedra results in darker turbid centers within thinner, clear rim. Irregular and patchy distribution of microcrystalline dolomite and fine-crystalline dolomite.

Tr. Authigenic subhedral quartz has dolomite inclusions. A later distribution of pyrite surrounds the quartz and dolomite.

Classification: fine-crystalline dolostone.

Thin section number: TC 10

Formation: Banff

Height above base of section in feet: 83 - 88

Petrographic Description

Composition of carbonate by X-ray determination:

98% dolomite

2% calcite

Constituents:

36% Terrigenous material:

36% Clay minerals: medium brown. Concentrated at boundaries of rhombohedra.

<1% Quartz: detrital. Very angular to subangular shapes, some with vacuoles. Average diameter 0.040 mm., diameter ranges from 0.015 to 0.080 mm.

Texture:

Size: coarse microcrystalline.

Alteration:

64% Replacement:

61% Dolomite: subhedra and anhedra contain smaller rhombohedra and nuclei of subrounded pyrite. Average 0.040 mm. diameter.

3% Pyrite: disseminated with organic material (?) as irregular elongate shapes. Pyrite altered to hematite.

Special features:

Quartz grain boundaries corroded, resulting in increase of angularity. 0.5 mm. diameter lighter patches of dolomite rhombohedra. Pyrite nodule of 2.5 by 4.5 mm. dimensions. A crescentic core of pyrite contains some argillaceous material. The core surrounded by a 0.5 mm. thick ring of light grey chert with much disseminated pyrite mainly concentrated at the outer margin. A few rounded "ghosts" with little pyrite occur in this ring. A ring of pyrite occurs between two layers of limonite which surround the chert. The pyrite and limonite fractured concentrically and radially, the fractures filled with chert. Void separates outer ring of limonite from dolomite.

Classification: coarse-microcrystalline argillaceous dolostone.

Thin section number: TC 11

Formation: Banff

Height above base of section in feet: 88 - 114

Petrographic Description

Composition of carbonate by X-ray determination:

89% calcite

11% dolomite

Constituents:

41% Oolites:

Concentric and radial structure. Nuclei of grey-brown cryptocrystalline calcite or fossil fragments. Regular rounded shapes, some fragmented, some concentric laminae incomplete. Superficial oolite diameter averages 0.295 mm. compared to 0.250 mm. diameter of oolites. Authigenic quartz present in some cryptocrystalline calcite nuclei, two pyritiferous nuclei. Oolite structure contain patches of brown cryptocrystalline calcite, possible algae borings.

6% Intraclasts:

Grey-brown cryptocrystalline calcite as in nuclei of oolites. Some inclusions of clear microcrystalline calcite present. No internal structure. Average diameter 0.25 mm.

25% Bioclasts:

19% Crinoids: columnals average diameter 0.320 mm. Numerous plates. Calcite cement in optical continuity.

4% Foraminifera: tube forms with thin walls of dark cryptocrystalline calcite, some very thin clear calcite lamellae parallel to length of tube. Interiors filled with clear microcrystalline calcite. Most straight or gently curved, no openings at the tube-ends, some are broken in situ. May be of algal origin.

1% Bryozoans: fragmented fronds of fibrous calcite with clear calcite in chambers.

1% Ostracods: articulate and disarticulate forms. Maximum height is 2.04 mm. Calcite cement or ooze fills the interiors. Walls recrystallized, some papillae or nodes.

<1% Echinoids: spine average diameter 0.15 mm.

2% Terrigenous material:

2% Clay minerals.

15% Interstitial materials:

15% Cement: microcrystalline to coarse-crystalline calcite in original pores.

Texture:

Size: medium sand.

Sorting: well.

Roundness and shape: rounded.

Fabric: moderately anisotropic.

Packing: moderate.

Microstructure: microstylolites are shown by clay mineral traces. Constituents are laminated.

Alteration:

11% Replacement:

11% Dolomite: rhombohedra average diameter 0.031 mm. Transect grain boundaries. About 3% replaces allochems.

Tr. Quartz: some replaces shells. Subhedral shape. Contains inclusions of pyrite.

Special features:

Most of the bioclasts have a coating of grey brown calcite ooze, probable mud coating at the time of deposition.

Classification: medium-grained dolomitized oosparite.

Thin section number: TC 12

Formation: Banff

Height above base of section in feet: 114 - 119

Petrographic Description

Composition of carbonate by X-ray determination:

98% dolomite

2% calcite

Constituents:

12% Terrigenous material:

12% Clay minerals: disseminated mainly in the microcrystalline dolomite laminae.

Texture:

Size: very fine crystalline.

Microstructure: irregular laminae of microcrystalline dolomite and very fine crystalline dolomite, frequently patchy.

Alteration:

87% Replacement:

85% Dolomite: smaller rhombohedra inclusions and exhibits zoning uncommonly. Two distinct sizes of rhombohedra. Smaller more uniform 0.015 mm. diameter size associated with clay minerals. The larger size maximum of 0.223 mm., averages 0.097 mm. Both size ranges subhedral to euhedral.

2% Pyrite: disseminated. More commonly with a framboidal texture along dolomite rhombohedra boundaries than as nuclei in the rhombohedra.

Special features:
Traces of organic material black in transmitted and incident light. 1% collophane with few inclusions. Elongate fragments are broken *in situ*.

Classification: very fine-crystalline argillaceous dolostone.

Thin section number: TC 13b

Formation: Pekisko

Height above base of section in feet: 119 - 190

Petrographic Description

Composition of carbonate by X-ray determination:

97% calcite

3% dolomite

Constituents:

82% Bioclasts:

42% Crinoids: diameter averages 0.71 mm. Clear calcite in optical continuity over grains. Boundaries generally abraded, some evidence of differential pressure-solution welding. Poorly preserved grains, brown ooze fills rotted portions at periphery.

20% Algae: clear microcrystalline calcite wall and dark microcrystalline calcite filling perforations. Various stages of recrystallization, some not readily differentiated from recrystallized foraminifera. Central cavity filled with bioclasts and ooze.

15% Foraminifera: planispiral forms, dark cryptocrystalline calcite walls. Microcrystalline calcite fills chambers. Preservation varies from good to poor, various stages of recrystallization to complete obliteration.

3% Gastropods: two large shells 3.75 and 5.11 mm. long. Clear microcrystalline calcite walls. Microcrystalline calcite fills chambers, crystals elongated normal to walls. Bioclasts in chamber of one gastropod. Exterior portion of wall dissolved on one specimen.

1% Ostracods: thin walls with fibres normal to wall.

1% Indeterminate: fibrous calcite.

3% Intraclasts:

Diameter averages 0.76 mm., boundaries poorly defined. No internal structure, possible recrystallized foraminifera. Brown microcrystalline calcite with dolomite rhombohedra, scattered pyrite and quartz inclusions.

14% Interstitial materials:

13% Cement: clear fine-to coarse-crystalline calcite.

1% Matrix: silt-sized calcite and ooze.

1% Terrigenous materials:

1% Clay minerals.

Texture:

Size: coarse sand.

Sorting: well.

Roundness and shape: rounded.

Fabric: isotropic.

Packing: moderate.

Microstructure: traces of microstylolites.

Alteration:

<1% Replacement:

<1% Dolomite: diameter averages 0.031 mm. Associated with pyrite, some transects fossil boundaries.

<1% Quartz: some replaces fibrous shells. Euhedra with inclusions.

<1% Pyrite: scattered.

Recrystallization:
Gastropod shells recrystalized to microcrystalline calcite.

Classification coarse grained crinoidal biosparite.

Thin section number: TC 13 - 29

Formation: Pekisko

Height above base of section in feet: 148

Petrographic Description

Composition of carbonate by X-ray determination:

97% calcite

3% dolomite

Constituents:

71% Bioclasts:

61% Crinoids: diameter averages 0.66 mm., maximum diameter 2.04 mm. Columnals abraded, some with cellular structure, brown ooze fills rotted portions. Calcite cement in optical continuity.

5% Bryozoans: chamber diameters average 0.15 mm. Ooze and clear microcrystalline calcite fills chambers. Fragmented to various degrees, some fragments aligned parallel to bedding.

5% Brachiopods: fragmented, undulatory shells with punctae. Some have thin outer prismatic layer.

<1% Echinoids: diameter averages 0.24 mm.

<1% Ostracods: height about 0.64 mm. Clear very fine-crystalline calcite in cavity.

4% Intraclasts:
Dark brown calcite ooze, some patches of microcrystalline calcite. Diameter averages 0.128 mm., spherical to elliptical shapes. Recrystallized bryozoan origin for some. Merge with matrix.

<1% Oolites: Rare.

6% Terrigenous materials:

6% Clay minerals: disseminated in matrix.

18% Interstitial materials:

14% Matrix: microcrystalline to cryptocrystalline calcite.

4% Cement: medium-to coarse-crystalline clear calcite cement.

Tr. Porosity.

Texture:

Size: coarse sand.

Sorting: poor.

Roundness and shape: angular.

Fabric: isotropic.

Packing: loose to moderate.

Microstructure: fractures up to 0.05 mm. wide filled with microcrystalline calcite.

Alteration:

1% Replacement:

1% Quartz: authigenic, replaces fossil debris.

Tr. Pyrite: disseminated.

Classification: coarse-grained crinoidal biomicrite.

Thin section number: TC 13-64

Formation: Pekisko

Height above base of section in feet: 183

Petrographic Description

Composition of carbonate by X-ray determination:

63% calcite

37% dolomite

Constituents:

45% Bioclasts:

43% Crinoids: diameter averages 0.66 mm., maximum diameter 1.43 mm. Fragmented.

2% Algae: partly silicified, contains a few dolomite rhombohedra. Possible coral fragmented.

<1% Bryozoans: fragmented, brown ooze in chambers.

<1% Brachiopods: fragmented, fibrous shells.

<1% Ostracods: 0.81 mm. height. Chamber filled with ooze.

<1% Oolite:
Diameter 0.288 mm. Superficial oolite with a thin discontinous coat of microcrystalline calcite over brown ooze.

1% Terrigenous material:

1% Clay minerals: irregularly distributed in very thin stringers. Red-brown in reflected light, associated with pyrite.

16% Interstitial material:

16% Matrix: ooze, strongly dolomitized.

Tr. Cement: in optical continuity over crinoids.

Texture:

Size: coarse sand.

Sorting: poor.

Roundness and shape: angular to subangular.

Fabric: isotropic.

Packing: loose.

Microstructure: some microstylolites.

Alteration:

38% Replacement:

36% Dolomite: diameter averages 0.040 mm., euhedral to subhedral. Replaces matrix. Some rhombohedra have a darker core and a lighter rim, some transect bioclast boundaries.

2% Quartz: anhedra and subhedra, commonly with inclusions of pyrite and carbonate. Replaces fossils and matrix.

Tr. Pyrite: framboidal texture.

Classification: coarse-grained dolomitized biomicrite.

Thin section number: TC 13-71

Formation: Pekisko

Height above base of section in feet: 190

Petrographic Description

Composition of carbonate by X-ray determination:

88% dolomite

12% calcite

Constituents:

11% Interstitial materials:

11% Matrix: scattered patches.

5% Terrigenous materials:

5% Clay minerals: finely disseminated.

Texture:

Size: coarse microcrystalline.

Alteration:

84% Replacement:

84% Dolomite: euhedra and subhedra diameters average 0.048 mm., uniformly sized.

<1% Quartz: partly surrounds rhombohedra, some with inclusions. Anhedra diameter averages 0.031 mm.

Tr. Pyrite: disseminated, framboidal texture.

Tr. Collophane: scattered.

Special features:
Rare crinoid columnals partly replaced by dolomite rhombohedra.

Classification: coarse-microcrystalline calcitic dolostone.

Thin section number: TC 14-22

Formation: Pekisko

Height above base of section in feet: 212

Petrographic Description

Composition of carbonate by X-ray determination:

90% dolomite

10% calcite

Constituents:

14% Terrigenous materials:

14% Clay minerals: disseminated.

7% Interstitial materials:

7% Matrix: fine crystalline calcite anhedra and subhedra, patches.

Texture:

Size: medium microcrystalline.

Alteration:

79% Replacement:

65% Dolomite: light brown rhombohedra, diameter averages 0.023 mm., uniform.

14% Chert: light brown chert with patches of lighter replacement chalcedony. Also common trapped dolomite euhedra, maximum diameter 0.46 mm., diameter averages 0.023 mm. Disseminated pyrite in chert. Some chert composed of microgranular quartz clearly of sponge spicule and crinoid replacement origin, some original structure. Chert distributed as irregular nodules.

Classification: medium-microcrystalline argillaceous cherty dolostone.

Thin section number: TC 16

Formation: Pekisko

Height above base of section in feet: 259 - 299

Petrographic Description

Composition of carbonate by X-ray determination:

92% calcite

8% dolomite

Constituents:

62% Bioclasts:

62% Crinoids: abraded, denticulated fragments; numerous pressure-solution boundaries between adjacent columnals. Fillings along grain outlines and axial canals of brown cryptocrystalline calcite, rare sparry calcite in axial canal. Diameter averages 0.209 mm.

12% Intraclasts:

Brown cryptocrystalline calcite, recrystallizing to microcrystalline calcite anhedra. Probable foraminiferal relicts included. Irregular boundaries owing to differential pressure-solution welding, shape spherical to elongate.

4% Terrigenous materials:

3% Clay minerals: concentrated by micro-stylolites.

1% Quartz: detrital, silt sized, clear, angular, boundaries corroded by carbonate, some strained.

14% Interstitial materials:

14% Matrix: comminuted bioclast debris and microcrystalline calcite, grades into ooze.

Tr. Porosity.

Texture:

Size: fine sand.

Sorting: poor.

Roundness and shape: very angular to subangular.

Fabric: isotropic.

Packing: moderate.

Microstructure: fracture veins filled with calcite.

Microstylolites common.

Alteration:

8% Replacement:

8% Dolomite: subhedra and euhedra, maximum diameter 0.088 mm., diameter averages 0.048 mm. Uncommonly transects bioclast boundaries, mainly in interstitial material, slightly clearer than calcite.

Special features:
Dull, thin, opaque partings of organic material. Pressure-solution welding of grains results in pseudo-anisotropic fabric.

Classification: fine-grained crinoidal biosiltite.

Thin section number: TC 17-22

Formation: Pekisko

Height above base of section in feet: 321

Petrographic Description

Composition of carbonate by X-ray determination:

97% calcite

3% dolomite

Constituents:

42% Bioclasts:

26% Brachiopods: thick, fibrous, light brown undulating layer overlain by thinner, light brown layer with crystals normal to the surface. The prismatic crystals slightly longer over crests in undulating shells which are articulate and disarticulate. Internal cavities filled with clear sparry calcite cement and mechanical sediments. Cement has two stages of development. Prismatic crystals in a layer up to 0.063 mm. thick mark first stage. A second stage of medium-crystalline cement fills remaining cavity. Geopetal arrangement of light grey calcite matrix under calcite cement of some shells, other shells entirely filled with matrix. Rare spines light walls and dark calcite filling interior cavities. Brachiopod diameters

greater than 2 mm.

10% Algae: encrusting light and dark brown irregularly laminated forms. Numerous examples of fragments. Dark laminae heavily hematitic stained. Tubelike forms of dark calcite, central cavity filled with microcrystalline to fine crystalline calcite.

<1% Foraminifera: planispiral forms largely recrystallized.

2% Bryozoans: recrystallized fragments with internal chambers filled with matrix.

2% Crinoids: columnals and calyx plates, rotted peripheral portions filled with dark calcite. Maximum diameter 0.83 mm., minimum diameter 0.21 mm. Evidence of algal bored plate.

2% Echinoids: poorly-reserved spines with maximum diameter 1.28 mm., minimum diameter 0.128 mm. Cellular structure exhibited by matrix-infiltrated lattice.

9% Intraclasts:

Rounded to subrounded spherical and ovate shapes of dark calcite. Maximum diameter 0.320 mm., diameter averages 0.080 mm. A few contain lighter coloured patches. The light grey matrix within fossil chambers contains intraclasts. Boundaries hazy with matrix. Bioclast origin for some.

21% Interstitial material:

18% Matrix: dark brown calcite ooze fills between brachiopods. A light to medium grey granoblastic calcite cement with dolomite rhombohedra fills brachiopod cavities.

3% Cement: clear sparry calcite fills fossil cavities and spaces under elongate shells. About 8% fills brachiopod cavities.

23% Terrigenous material:

23% Clay minerals: disseminated in matrix and concentrated by microstylolites.

Texture:

Size: fine pebble.

Sorting: poor.

Fabric: isotropic.

Packing: loose.

Microstructure: microstylolites exhibited by clay mineral and remanent fossil structures.

Alteration:

5% Replacement:

3% Dolomite: some in cement, rhombohedra in matrix average 0.031 mm. diameter and confined to one end of the slide.

2% Pyrite: altered to hematite, gives dark calcite ooze a red-brown stain in reflected light.

Classification: fine-pebble brachiopodal biomicrudite.

Thin section number: TC 19

Formation: Pekisko

Height above base of section in feet: 329 - 339

Petrographic Description

Composition of carbonate by X-ray determination:

62% dolomite

38% calcite

Constituents:

34% Terrigenous materials:

33% Clay minerals: brown, indistinctly laminated.

1% Quartz: detrital, clear angular grains, diameter averages 0.031 mm., forms quartz grain laminae.

24% Interstitial materials:

24% Matrix: ooze.

Texture:

Size: medium microcrystalline.

Microstructure: distribution of clay minerals results in laminae.

Alteration:

42% Replacement:

39% Dolomite: rhombohedra diameter averages 0.023 mm. Patches of slightly larger clearer rhombohedra. Maximum diameter 0.063 mm.

3% Pyrite: framboidal, disseminated.

Classification: medium-microcrystalline calcitic argillaceous dolostone.

Thin section number: TC 21A

Formation: Shunda

Height above base of section in feet: 367 - 396

Petrographic Description

Composition of carbonate by X-ray determination:

97% calcite

3% dolomite

Constituents:

25% Intraclasts:
Rounded, elliptical and spherical shapes. Medium to dark grey-brown cryptocrystalline calcite. Inclusions of foraminifera, grains, dolomite rhombohedra, and lighter patches of calcite. Boundaries not sharply defined. Maximum diameter 1.64 mm., diameter averages 0.40 mm.

3% Bioclasts:

2% Brachiopods: long curved shell of fibrous calcite. Smaller abraded fragments present. Spines thin to thick walled with clear sparry and cryptocrystalline calcite in chambers.

1% Calcispheres: thin dark walls with clear calcite centers.

62% Interstitial materials:

47% Matrix: medium to dark grey cryptocrystalline calcite, material identical to that composing intraclasts.

15% Cement: clear and sparry cement.

Tr. Porosity: intercrystalline porosity.

9% Terrigenous materials:

9% Clay minerals: disseminated.

Texture:

Size: medium sand.

Sorting: poor.

Roundness and shape: subrounded, subspherical.

Fabric: isotropic.

Packing: loose.

Microstructure: hairlike fracture veins cut intraclasts.

Alteration:

1% Replacement:

1% Dolomite: euhedra replace matrix and cement. A trace of limonitic stain on outer borders of rhombohedra, replaces cement.

Tr. Pyrite: locally concentrated, altered to hematite.

Classification: medium-grained intramicrite.

Thin section number: TC 21B

Formation: Shunda

Height above base of section in feet: 367 - 396

Petrographic Description

Composition of carbonate by X-ray determination:

97% calcite

3% dolomite

Constituents:

12% Bioclasts:

8% Foraminifera: planispiral types rare; fragmented rectilinear septate type common. Clear thin to thick walled, chambers filled with grey-brown and clear calcite.

3% Ostracods: clear calcite walls, articulate, interiors filled with cement. Specimen crushed in situ.

<1% Echinoids: single spine with cellular structure filled with cryptocrystalline calcite.

1% Calcispheres: clear microcrystalline calcite nuclei with a thin dark rim.

80% Interstitial material:

60% Matrix: 58% grey-brown ooze containing patches of lighter comminuted fragments and scattered microgranular quartz. 2% silt-sized calcite.

18% Cement: clear sparry calcite, rare crystals have stained border.

Tr. Porosity: intercrystalline.

5% Terrigenous materials:

5% Clay minerals: concentrated at microstylolites.

Texture:

Microstructure: microstylolites present shown by clay.

Alteration:

3% Replacement:

3% Dolomite: euhedra diameter averages 0.031 mm., mainly in patches of light grey cryptocrystalline calcite closely associated with cement. Light grey calcisiltite appears to be mechanical filling of original pore spaces - geopetal accumulation. Some straining.

Classification: foraminiferal biomicrite.

Thin section number: TC 27

Formation: Shunda

Height above base of section in feet: 444 - 456

Petrographic Description

Composition of carbonate by X-ray determination:

64% calcite

36% dolomite

Constituents:

- 58% Interstitial materials:
  - 52% Matrix: medium brown-grey cryptocrystalline calcite, diameter averages 0.001 mm.
  - 6% Porosity.
- 4% Bioclasts:
  - 1% Brachiopods: long curved clear shell.
  - 2% Calcispheres: clear microcrystalline calcite nuclei with dark coating of calcite. Diameter ranges from 0.031 to 0.063 mm. Some have corona structure, some have thin clear coating over dark layer.
  - 1% Foraminifera: coating of clear cryptocrystalline calcite over dark nucleus. Diameter ranges from 0.031 to 0.063 mm.
- 5% Terrigenous materials:
  - 5% Clay minerals: disseminated.

Texture:

Size: cryptocrystalline.

Microstructure: poorly developed microstylolites.

Alteration:

- 33% Replacement:
  - 32% Dolomite: euhedra and subhedra, diameter

averages 0.056 mm., maximum diameter 0.160 mm. Some staining on edges.

1% Pyrite: disseminated.

Special features:
Distribution of slightly lighter coloured brown-grey calcite often gives the rock an "intraclastic" appearance. Lighter calcite diameter averages 0.003 mm.

Classification: dolomitized fossiliferous micrite.

Thin section number: TC 28b

Formation: Shunda

Height above base of section in feet: 456 - 498

Petrographic Description

Composition of carbonate by X-ray determination:

97% calcite

3% dolomite

63% Intraclasts:
Rounded, elliptical, some irregularly rounded shapes. Diameter ranges from 0.050 to 0.61 mm. Grain boundaries rarely sharp, have microcrystalline layer between cement and grain on some. Some lighter microcrystalline patches. No internal structure.

22% Interstitial material:

19% Cement: medium to coarse crystalline clear calcite.

3% Matrix: brown-grey ooze, same material composes intraclasts.

3% Bioclasts:

<1% Crinoids: single elongate columnal.

1% Foraminifera: rounded and elliptical cross-sections. Diameter averages 0.160 mm.

2% Algae?: two separate tubelike features of dark cryptocrystalline calcite filled with turbid calcite.

12% Terrigenous materials:

12% Clay minerals: disseminated.

Texture:

Size: medium sand.

Sorting: poor.

Roundness and shape: subrounded, elliptical.

Fabric: isotropic.

Packing: loose.

Alteration:

<1% Replacement:

<1% Dolomite: limonite stained rims.

Classification: medium-grained argillaceous intrasparite.

Thin section number: TC 32

Formation: Shunda

Height above base of section in feet: 576 - 587

Petrographic Description

Composition of carbonate by X-ray dtermination:

94% calcite

6% dolomite

Constituents:

40% Oolites:
Spherical and elliptical shapes, concentric laminae with faint radial structure. Dark grey-brown and lighter brown laminae of cryptocrystalline calcite. Nuclei of grey-brown cryptocrystalline calcite. Diameter averages 0.91 mm., maximum diameter 1.79 mm.

12% Intraclasts:
Dark grey-brown microcrystalline calcite, spherical and elliptical shapes. No internal structure. Diameter averages 0.088 mm., maximum diameter 0.40 mm.

40% Interstitial materials:

10% Cement: clear sparry calcite.

30% Matrix: dark grey-brown ooze.

Tr. Porosity: intercrystalline porosity in cement.

2% Terrigenous material:

2% Clay minerals: disseminated.

Texture:

Size: coarse sand.

Sorting: poor.

Roundness and shape: rounded, spherical.

Fabric: isotropic.

Packing: loose.

Microstructure: well developed microstylolites.

Alteration:

6% Replacement:

6% Dolomite: subhedra in calcite cement, in nuclei and laminae of oolites, and in matrix. Some stained rims. Diameter averages 0.048 mm., up to 0.40 mm. diameter.

Classification: coarse-grained intraclastic oomicrite.

Thin section number: TC 33u

Formation: Shunda

Height above base of section: 587 - 610

Petrographic Description

Composition of carbonate by X-ray determination:

74% dolomite

26% calcite

Constituents:

36% Terrigenous material:

28% Clay minerals: concentrated at dolomite edges.

8% Quartz: detrital, unstrained, clear, elongate to equidimensional, very angular to subangular, dolomite corroded boundaries.

18% Interstitial material:

18% Matrix: patches of cryptocrystalline calcite.

Texture:

Size: coarse microcrystalline.

Microstructure: concentrations of clay minerals result in poorly defined laminae.

Alteration:

46% Replacement:

42% Dolomite: subhedra with smaller inclusions. Maximum diameter up to 0.097 mm., diameter averages 0.048 mm.

2% Chert: microgranular quartz and some grains with inclusions. Small nodules poorly defined, cut by thin carbonate stringers.

2% Pyrite: locally concentrated, disseminated, altered to hematite.

Special features:
Rare grains of collophane and platey mineral with a low birefringence (possible mica).
Black opaque organic materials are scattered.
Irregular structure possibly caused by burrowing organisms.

Classification: coarse-microcrystalline calcitic argillaceous dolostone.

Thin section number: TC 34b

Formation: Turner Valley

Height above base of section in feet: 610 - 628

Petrographic Description

Composition of carbonate by X-ray determination:

69% calcite

31% dolomite

Constituents:

2% Bioclasts:

2% Foraminifera: diameter averages 0.128 mm., maximum diameter 0.177 mm. Rounded shapes with slightly darker outer rim, or a slightly darker core. Chambers filled with clear microcrystalline calcite. Rare elongate shapes.

63% Interstitial materials:

61% Matrix: medium to dark brown-grey ooze.

2% Porosity: fracture and intergranular porosity.

7% Terrigenous materials:

7% Clay minerals: dark brown, disseminated.

Texture:

Size: cryptocrystalline.

Microstructure: microstylolites shown by clay minerals. Network of fissure veins filled with microcrystalline to fine-crystalline calcite anhedra.

Alteration:

28% Replacement:

28% Dolomite: diameter averages 0.063 mm., maximum diameter 0.120 mm.

<1% Pyrite: localized, altering to hematite.

<1% Quartz: subhedra and euhedra, diameter averages 0.023 mm.

Special features:

Darker patches present in ooze, some have faint spherical or elliptical outlines, possible recrystallized intraclasts or clots.

Classification: foraminiferal micrite.

Thin section number: TC 36

Formation: Turner Valley

Height above base of section in feet: 641 - 680

Petrographic Description

Composition of carbonate by X-ray determination:

98% dolomite

2% calcite

Constituents:

9% Interstitial materials:

9% Clay minerals: disseminated.

Texture:

Size: very fine crystalline.

Microstructure: poorly developed microstylolites. Fracture veins filled with carbonate.

Alteration:

89% Replacement:

89% Dolomite: two distinct sizes of dolomite anhedra and subhedra. Lighter coloured smaller (averages 0.088 mm.) size and darker light brown (averages 0.150 mm.) size.

Special features:
Change of crystal size and colour shows along curved shape similar to brachiopod shell.
Uncommon grains of collophane.

Classification: very fine-crystalline dolostone.

Thin section number: TC 41

Formation: Mount Head

Height above base of section in feet: 927 - 941

Petrographic Description

Composition of carbonate by X-ray determination:

87% dolomite

13% calcite

Constituents:

11% Bioclasts:

Irregular patches of calcite with boundaries denticulated. Shape and alignment simulate crinoid columnals, brachiopod shells, and bryozoans.

9% Terrigenous materials:

9% Clay minerals: disseminated.

Texture:

Size: coarse microcrystalline.

Microstructure: 3/4 inch bed of coarser dolomite rhombohedra between finer dolomite rhombohedra.

Alteration:

80% Replacement:

72% Dolomite: two distinct sizes, smaller size 0.008 mm. and larger 0.037 mm. Zoning.

8% Chert: microgranular, colorless, diameter of grains averages 0.008 mm. Rhombohedral outlines filled with quartz, calcite leached. Sharp boundary with calcite "eye". Distributed regularly and patchy in adjacent dolomite.

Special features:
Very coarse-crystalline calcite patch is "eye", boundary denticulated by dolomite rhombohedra, core partly replaced by dolomite.

Classification: coarse-microcrystalline cherty bioclastic dolostone.

Thin section number: TC 43

Formation: Mount Head

Height above base of section in feet: 971 - 977

Petrographic Description

Composition of carbonate by X-ray determination:

96% dolomite

4% calcite

Constituents:

3% Bioclasts: crinoid columnals, diameter average 0.097 mm., partly replaced by dolomite. Elongate shapes probably brachiopods. Bryozoan fronds outlined.

10% Interstitial materials:

10% Porosity: microcrystalline dolomite rhombohedra rim the pores. Some porosity from leaching of crinoids.

12% Terrigenous materials:

12% Clay minerals: evenly distributed, a few thin undulating partings.

Texture:

Size: very fine crystalline.

Alteration:

75% Replacement:

73% Dolomite: diameters average 0.015 mm., and 0.072 mm. Larger size anhedral and subhedral, distributed in patches. Simulate crinoid columnals, brachiopods, and bryozoans.

1% Chert: very fine crystalline quartz with abundant inclusions, replaces long curved shell. Scattered patches of microgranular quartz, some larger subhedral crystals.

1% Pyrite: disseminated and locally concentrated, altered to hematite.

Classification: very fine-crystalline porous argillaceous dolostone.

Thin section number: TC 52

Formation: Rocky Mountain

Height above base of section in feet: 1330 - 1331

Petrographic Description

Constituents:

65% Phenoclasts:

50% Chert pebble: diameter 22 mm. Pebble of light brown concentrically banded chalcedony over nuclei of chert. Chert of microcrystalline to cryptocrystalline quartz with numerous spherical and rhombic inclusions. Pebble contains sponge spicules and a medium brown quartz portion separating an inner core of light brown spicules, chalcedony and microgranular quartz from chalcedonic spherulites. Medium brown quartz weakly anisotropic, cryptocrystalline, contains very fine-grained, angular grains of quartz, brown microgranular quartz, and chalcedonic spicules having multiple growth centres for the fibres. Monaxonic spicule diameter ranges from 0.063 to 0.272 mm., show axial canal and/or external cover of material similar to matrix. Clear microgranular quartz replaced a portion or all of some spicules. Light brown core of microgranular quartz with irregularly distributed clear patches of chalcedonic spherulites. Outer portion of light brown core contain spicules recrystallized to microgranular quartz and chalcedony. Angular quartz grains present.

2% Sandstone rock fragment: very fine-grained clear unstrained quartz, clear quartz overgrowths in structural continuity. Equidimensional. Microgranular quartz in interstices.

10% Chert: microcrystalline to cryptocrystalline light brown quartz with numerous relict spicules. Very weak birefringence. Red-brown hematitic stain disseminated and locally concentrated, trace of pyrite pseudomorph. Partly dissolved grain of glauconite in one phenoclast.

3% Quartz: detrital, floating in matrix. angular to subrounded, clear unstrained grains.

Tr. Zircon and Collophane: detrital.

33% Interstitial material:

30% Matrix: brown, cryptocrystalline, isotropic phosphatic material. Evidence of solution by matrix of phenoclasts by (1) transected spherulites, (2) wide and narrow embayments in phenoclasts.

3% Porosity.

Texture:

Sorting: poor.

Roundness and shape: very angular to angular, variable shape.

Fabric: isotropic.

Packing: loose.

Microstructure: colloform structure in chert pebble.

Alteration:

2% Replacement:

2% Quartz: microcrystalline to very fine-crystalline, preserves fibrous structure of shell fragments. Some portions very weakly birefringent.

Recrystallization:

Opal recrystallized to chalcedony.

Special features:
The phosphatic matrix is partly of replacement orgin, as shown by the transected spherulites.
Red-brown hematite is locally concentrated at the exterior of pebble, some in chert rock fragments, some replaces spicules.
Some has framboidal texture.

Classification: chert pebble conglomerate.

Thin section number: TC 53

Formation: Rocky Mountain

Height above base of section in feet: 1331 - 1522

Petrographic Description

Alteration:

100% Replacement:

100%	Chert: colorless to cryptocrystalline to mainly microcrystalline quartz. Patchy coarse microcrystalline and very fine-crystalline quartz, overgrowth structure over rhombic, rounded, and elongate forms.
Tr.	Hematite: disseminated, rarely replaces spicules.

Special features:
Relict spicules are abundant, also microgranular grains of phosphatic material.
A single grain of tourmaline.

Classification: spicular chert.

Thin section number: TC 54

Formation: Rocky Mountain

Height above base of section in feet: 1522 - 1547

Petrographic Description

Composition of carbonate by X-ray determination:

0% dolomite

0% calcite

Constituents:

92% Terrigenous material:

75%	Quartz: detrital, clear, diameter ranges from 0.048 to 0.223 mm., diameter averages 0.097 mm. Overgrowths of clear quartz in structural continuity, pressure-solution welding of some grains. Numerous grains have fine hairline fractures, strained and unstrained grains.
5%	Chert: grains of microcrystalline chert with common phenoclasts of quartz as above, impure collophane, glauconite?, and leucoxene.
12%	Phosphatic material: partly authigenic, mainly detrital. Impure type has incomplete

extinction, grades to pure collophane with complete extinction. Some relict spicules. Single relict spicules. Single grain with a quartz nucleus.

Tr. Tourmaline and rare grains of glauconite?

8% Interstitial materials:

2% Cement: weakly anisotropic impure phosphatic material. Hematitic stain in reflected light. Traces of silica overgrowths.

6% Porosity.

Texture:

Size: very fine sand.

Sorting: well.

Roundness and shape: angular, equidimensional to subrectangular.

Packing: dense.

Classification: very fine-grained quartzose sandstone.

[illegible]

[illegible]

A small piece of [illegible] mesh screen, weighed, and digested in [illegible] hydrochloric acid. The insoluble residue was filtered from solution, [illegible], weighed, and examined under a binocular microscope.

Ireland (1958) has [illegible] used for describing insoluble residues.

chert: cryptocrystalline [illegible] of color; composed [illegible] microscopic [illegible] particles [illegible] to nonresolvable [illegible]

dolomolds: rhombohedral [illegible]

dolomoldic: containing [illegible]

drusy: clusters of [illegible] inclusions.

granular: chert [illegible] conglomerate [illegible] granules [illegible]

granulated: grains [illegible] aggregates [illegible] boundary [illegible] to drusy, [illegible]

Table 5. Insoluble Residues of the Thornton Creek Section.

Sample Number	Sample Weight Gms.	Insoluble Residue Wt. Gms.	Weight Per cent Insoluble Residue	Description of Insoluble Residue
TC 51	8.94	1.27	14.1	very light-brown-grey mud.
TC 50	14.27	0.85	6.0	dolomoldic to compact white to medium-grey chert; 25% brown-grey mud.
TC 49	8.46	0.77	9.1	silt-sized quartz subhedra and granulated quartz. Some organic material and brown-grey mud.
TC 48	7.82	1.55	19.8	very light-brown-grey mud; trace of chert.
TC 47	7.09	0.34	4.8	dolomoldic green and white chert and flakes and rods of granulated white quartz; 75% brown-grey mud.
TC 46	9.66	0.92	9.5	brown-grey mud with trace compact to granulated chert and quartz.
TC 45	8.57	0.98	11.5	brown-grey mud and 35% white to clear chert with some dolomolds.
TC 44	6.95	0.81	11.7	very light-brown-grey mud.
TC 43	9.19	1.28	11.0	light-brown-grey mud with trace of medium grey compact chert.
TC 42	8.28	1.68	20.3	angular frosted sand grains, frosted silt-sized quartz, granulated clear quartz, brown-grey mud, minor organic matter.
TC 41	5.21	0.89	17.1	equal amounts of silt-sized quartz and dark brown-grey mud.
TC 40	9.75	0.85	8.7	euhedral silt-sized quartz and dark-grey mud.

Table 5 (continued)

Sample Number	Sample Weight Gms.	Insoluble Residue Wt. Gms.	Weight Per cent Insoluble Residue	Description of Insoluble Residues
TC 39	5.09	0.55	10.9	brown-grey mud with some granulated to dolomoldic chert.
TC 38	7.89	0.82	10.4	brown-grey mud with minor silt-sized quartz, pyrite, and limonite-stained grains.
TC 37	5.09	0.55	[illegible]	brown-grey mud with some granulated to dolomoldic chert.
TC 36	9.57	0.83	8.7	brown-grey mud.
TC 35	7.41	0.70	[illegible]	granulated to dolomoldic chert, brown-grey mud and organic material.
TC 34b	11.98	0.81	[illegible]	brown-grey mud with some organic material.
TC 33u	9.39	[illegible]	10.4	brown-grey mud.
TC 33-1/	5.95	1.48	[illegible]	light-brown-grey mud.
TC 33b	5.67	0.23	4.0	medium-brown-grey mud.
TC 32	4.85	0.09	[illegible]	brown-grey mud, [illegible] silt-sized quartz.
TC 31b	10.33	[illegible]	[illegible]	brown-grey mud, [illegible] material.
TC 30u	13.37	1.02	[illegible]	dark-brown-grey mud.
TC 30	8.27	0.94	[illegible]	brown-grey mud, [illegible] organic material.
TC 29B	[illegible]	[illegible]	[illegible]	[illegible]
TC 29A	9.07	[illegible]	[illegible]	brown-[illegible]
TC 28	[illegible]	[illegible]	[illegible]	[illegible] 50% [illegible]

Table 5 (continued)

Sample Number	Sample Weight Gms.	Insoluble Residue Wt. Gms.	Weight Per cent Insoluble Residue	Description of Insoluble Residue
TC 28b	9.65	1.09	11.6	euhedral silt-sized quartz, 50% dark grey mud.
TC 27	12.98	0.79	6.1	dark-grey mud, trace of angular silt-sized quartz.
TC 26	7.47	2.73	36.6	light-grey-brown mud.
TC 25	5.29	0.22	4.2	brown-grey mud; subhedral and euhedral silt-sized quartz.
TC 24	8.35	0.94	11.4	dark-grey mud, rare clear subhedral quartz.
TC 24b	9.04	0.56	6.2	brown-grey mud with trace organic material.
TC 23	11.58	0.25	2.2	brown-grey mud.
TC 22	7.93	0.68	8.5	brown-grey mud.
TC 21B	13.52	0.66	4.9	dark grey mud, organic rich.
TC 21A	7.14	0.63	8.9	brown-grey mud, organic material and minor silt-sized quartz.
TC 20B	10.40	0.62	5.9	dark-grey to black mud, organic rich.
TC 20A	4.13	0.48	13.0	20% subhedral to euhedral silt-sized quartz, hematitic stained grains, organic material; 80% dark-grey mud.
TC 19	7.26	2.65	36.6	brown-grey mud.
TC 18-4	3.45	0.30	8.8	brown-grey mud.
TC 18	14.84	1.42	9.5	brown-grey mud, traces of silt-sized quartz, flakes and cubes of pyrite, and limonitic stained grains.
TC 17-22	4.87	1.23	25.1	brown-grey mud.
TC 17-13	3.67	0.62	16.8	brown-grey mud.

Table 5 (Continued)

Sample Number	Sample Weight Gms.	Insoluble Residue Wt. Gms.	Weight Per cent Insoluble Residue	Description of Insoluble Residue
TC 17	7.29	0.34	4.6	dark-grey mud, traces of rounded, frosted quartz grains.
TC 17b	6.75	0.76	11.3	dark-grey mud.
TC 16-5	7.79	0.20	2.5	subhedral to euhedral quartz grains, organic material and 50% dark-grey mud.
TC 16	3.89	0.16	4.0	dark-grey mud, trace quartz euhedra, organic rich.
TC 15-11	5.34	1.48	27.8	equal amounts of silt-sized quartz and mud. Trace of medium-grey granulated quartz.
TC 15	4.68	0.97	20.7	granulated quartz and 50% brown-grey mud, trace organic material.
TC 14-45	5.92	0.18	3.1	subhedral quartz, granulated quartz, dark-grey mud.
TC 14-32	5.22	0.32	6.1	druzy, granulated and euhedral quartz, dark-grey mud, organic rich.
TC 14-22	13.81	3.80	27.5	brown-grey mud and medium grey chert with scattered dolomoids.
TC 14	3.65	0.50	14.8	brown-grey mud with 10% granulated quartz and quartz euhedra.
TC 13-71	11.23	0.58	5.2	dark-brown-grey mud.
TC 13-64	6.09	0.17	2.9	granulated quartz, organic material, mud.
TC 13-[illegible]	[illegible].96	0.3[illegible]	7.2	silt sized quartz, granulated quartz and organic material.

Table 5 (continued)

Sample Number	Sample Weight Gms.	Insoluble Residue Wt. Gms.	Weight Per cent Insoluble Residue	Description of Insoluble Residue
TC 13b	7.00	0.08	1.2	silt-sized quartz and pyrite.
TC 12	12.77	1.81	14.1	brown-grey mud with trace of pyrite.
TC 11	8.62	0.17	1.9	dark-brown-grey mud.
TC 10	8.88	3.48	39.1	brown-grey mud.
TC 9u	6.83	0.26	3.9	brown-grey mud with trace or silt-sized quartz.
TC 9	4.72	0.14	3.0	brown-grey mud.
TC 8B	7.25	0.54	7.5	brown-grey mud.
TC 8A	6.74	1.98	29.4	brown-grey mud, trace organic material.
TC 7	8.58	2.83	32.9	brown-grey mud.
TC 6	7.29	1.69	15.0	brown-grey mud with 5% medium-grey granulated chert, soft.
TC 5	6.06	2.67	44.1	granulated quartz with laminae perceptible. 50% brown-grey mud.
TC 4	11.09	0.90	8.1	brown-grey mud.
TC 3	7.13	5.34	75.0	granulated quartz with laminae perceptible. 30% mud.
TC 2	14.71	2.46	16.7	brown-grey mud.
TC 1	6.22	0.20	4.5	brown-grey mud and trace of granulated quartz.

APPENDIX D

X-RAY DETERMINATION OF CALCITE-DOLOMITE RATIOS

Sample Preparation And Instrumentation

Pure samples of calcite and dolomite were used to construct a standard calibration curve. Samples X-rayed, including the unknowns, were ground manually in an agate mortar until the entire sample passed through a 230 mesh U.S. Standard sieve. In addition, the calcite and dolomite mixtures used for calibration purposes were mixed in acetone to ensure a homogeneous mixture. A portion of each sample was fixed to a glass slide with aroclor and ground lightly in 320 mesh carborundum until a flat surface was achieved.

Nickel filtered copper X-radiation, a geiger-counter tube, and a Brown recorder were used to produce the X-ray patterns. Each slide was scanned from 28° to 32° 2θ at 1/8° 2θ per minute using a scale factor of 16, multiplier of 1, and a time constant of 4.

A planimeter was used to measure the areas under the peaks.

Calculation Of The Standard Curve

Two mounts were made of each calcite-dolomite mixture, and each mount was run twice (Table 6). The two values obtained from each mount were averaged, and using the method of least squares, a calibration curve constructed for each set of mounts. These two curves were again averaged, and the resultant is the standard curve used (Fig. 6). Detection limits of 2.6 and 97.9 per cent dolomite were achieved. A maximum deviation of ± 7 weight per cent dolomite occurred during the construction of the curve.

Table 6. Calcite-Dolomite Calibration Data

Weight % Dolomite	Mount	Run	Calcite 104 (area)	Dolomite 104 (area)	Dolomite 104 / Dolomite 104 plus Calcite 104
90	1	a	38.96	446.75	0.92
90	1	b	29.87	402.59	0.93
90	2	a	33.76	336.16	0.91
90	2	b	38.96	342.85	0.90
80	1	a	74.02	345.45	0.82
80	1	b	64.93	248.05	0.79
80	2	a	55.84	257.14	0.82
80	2	b	49.35	225.90	0.82
60	1	a	124.67	153.24	0.55
60	1	b	137.66	164.93	0.55
60	2	a	240.25	344.15	0.59
60	2	b	219.48	411.68	0.65
50	1	a	168.83	142.85	0.46
50	1	b	128.57	129.87	0.50
50	2	a	220.77	215.58	0.49
50	2	b	216.88	216.88	0.50
40	1	a	197.40	102.59	0.34
40	1	b	171.42	144.15	0.46
40	2	a	280.51	150.64	0.35
40	2	b	283.11	146.75	0.34
20	1	a	210.38	58.44	0.22
20	1	b	197.40	50.65	0.20
20	2	a	345.45	119.48	0.26
20	2	b	337.66	124.67	0.27

Table 6 (continued)

Weight % Dolomite	Mount	Run	Calcite 104 (area)	Dolomite 104 (area)	$\frac{\text{Dolomite 104}}{\text{Dolomite 104 plus Calcite 104}}$
10	1	a	177.92	22.07	0.11
10	1	b	206.49	32.46	0.14
10	2	a	412.98	38.96	0.09
10	2	b	418.18	33.76	0.08

Table 7 Diffraction Analyses for Calcite and Dolomite in the Thornton Creek Section

Sample Number	Height above base feet	Calcite 104 (area)	Dolomite 104 (area)	$\frac{\text{Dolomite 104}}{\text{Dolomite 104 plus Calcite 104}}$	Weight per cent Dolomite
TC 54	1522-1547	0.0	0.0	0.00	0
TC 51	1233-1330	0.0	371.4	1.00	>98
TC 50	1190-1233	0.0	367.5	1.00	>98
TC 49	1113-1190	0.0	407.8	1.00	>98
TC 48	1100-1113	0.0	327.3	1.00	>98
TC 47	1042-1100	0.0	494.8	1.00	>98
TC 46	1024-1042	0.0	353.2	1.00	>98
TC 45	989-995	0.0	397.4	1.00	>98
TC 44	977-989	0.0	432.5	1.00	>98
TC 43	971-977	5.2	440.3	0.98	96
TC 42	941-971	27.3	413.0	0.94	91
TC 41	927-941	42.9	341.6	0.89	87
TC 40	902-927	284.4	119.5	0.30	31
TC 39	770-902	63.6	339.0	0.84	82
TC 38	702-766	0.0	487.0	1.00	>98
TC 37	680-702	184.4	144.2	0.44	43
TC 36	641-680	tr.	418.2	1.00	>98
TC 35	628-641	0.0	479.2	1.00	>98
TC 34b	610-628	227.3	139.0	0.30	31
TC 33u	587-610	59.7	184.4	0.75	74
TC 33-17	604	168.8	131.2	0.44	44
TC 33b	587-610	283.1	87.0	0.24	25
TC 32	576-587	315.6	13.0	0.04	6

Table 7 (continued)

Sample Number	Height above base feet	Calcite 104 (area)	Dolomite 104 (area)	Dolomite 104 / Dolomite 104 plus Calcite 104	Weight per cent Dolomite
TC 31b	554-576	268.8	7.8	0.03	5
TC 30u	509-553	366.2	0.0	0.00	<3
TC 30	509-553	193.0	131.2	0.49	49
TC 29B	498-509	93.5	98.7	0.51	50
TC 29A	498-509	131.2	140.3	0.52	52
TC 28	456-498	361.0	20.8	0.05	7
TC 28b	456-498	441.6	0.0	0.00	<3
TC 27	444-456	325.7	177.9	0.35	36
TC 26	443-444	27.3	281.8	0.91	89
TC 25	439-443	272.7	70.1	0.20	21
TC 24	424-439	416.9	51.9	0.11	13
TC 24b	424-439	371.4	0.0	0.00	<3
TC 23	401-424	381.8	40.3	0.10	12
TC 22	396-401	409.1	35.1	0.08	10
TC 21B	367-396	392.2	6.49	0.00	<3
TC 21A	367-396	339.0	tr.	0.00	<3
TC 20B	339-367	359.7	0.0	0.00	<3
TC 20A	339-367	375.3	0.0	0.00	<3
TC 19	329-339	70.1	118.2	0.63	62
TC 18-4	325	224.7	5.2	0.23	24
TC 18	321-329	368.8	57.1	0.13	15
TC 17-22	321	277.9	tr.	0.00	<3
TC 17-13	321	231.2	19.5	0.08	10

Table 7 (continued)

Sample Number	Height above base feet	Calcite 104 (area)	Dolomite 104 (area)	Dolomite 104 / Dolomite 104 plus Calcite 104	Weight per cent Dolomite
TC 17	299-321	350.6	0.0	0.00	<3
TC 17b	299-321	392.20	tr.	0.00	<3
TC 16-5	264	432.5	23.4	0.51	51
TC 16	259-299	431.2	26.0	0.06	8
TC 15	245-259	84.4	187.0	0.69	68
TC 15b	245-259	370.1	0.0	0.00	<3
TC 14-45	235	363.6	0.0	0.00	<3
TC 14-32	222	250.6	139.0	0.36	37
TC 14-22	212	23.4	254.5	0.92	90
TC 14	190-245	272.7	176.6	0.39	40
TC 13-71	190	45.5	418.2	0.90	88
TC 13-64	183	214.3	119.5	0.36	37
TC 13-29	148	358.4	tr.	0.00	<3
TC 13b	119-190	451.9	tr.	0.00	<3
TC 12	114-119	0.0	306.5	1.00	>98
TC 11	88-114	346.8	33.8	0.09	11
TC 10	83-88	0.0	324.7	1.00	>98
TC 9u	65-83	22.1	453.2	0.95	93
TC 9	65-83	19.5	442.9	0.96	94
TC 8B	59-65	224.2	240.8	0.50	50
TC 8A	59-65	94.8	244.2	0.72	71
TC 7	51-59	0.0	227.3	1.00	>98
TC 6	50-51	184.4	146.8	0.44	44

Table 7 (continued)

Sample Number	Height above base feet	Calcite 104 (area)	Dolomite 104 (area)	Dolomite 104 / Dolomite 104 plus Calcite 104	Weight per cent Dolomite
TC 5	40-50	105.2	132.5	0.56	56
TC 4	34-40	411.7	33.8	0.08	8
TC 3	32-34	32.5	55.8	0.63	62
TC 2	5-32	322.1	19.5	0.06	8
TC 1	0-5	426.0	22.1	0.05	7

EXPLANATION OF PLATE 1

Photomicrographs of Thin Sections

Figure 1: Intrasparite; section TC 18, Pekisko Formation, very fine-grained intrasparite with dolomitization "front" on left obliterating textural features. (x25), plane polarized light.

Figure 2: Intrasparite; section TC 28b, poorly sorted intraclasts cemented with clear calcite. Note merging of grain boundaries. (x25), plane polarized light.

Figure 3: Biomicrudite; TC 17-22, Pekisko Formation, articulate brachiopod showing geopetal accumulation of sediment in cavity. Matrix of dark calcite ooze. (x25), plane polarized light.

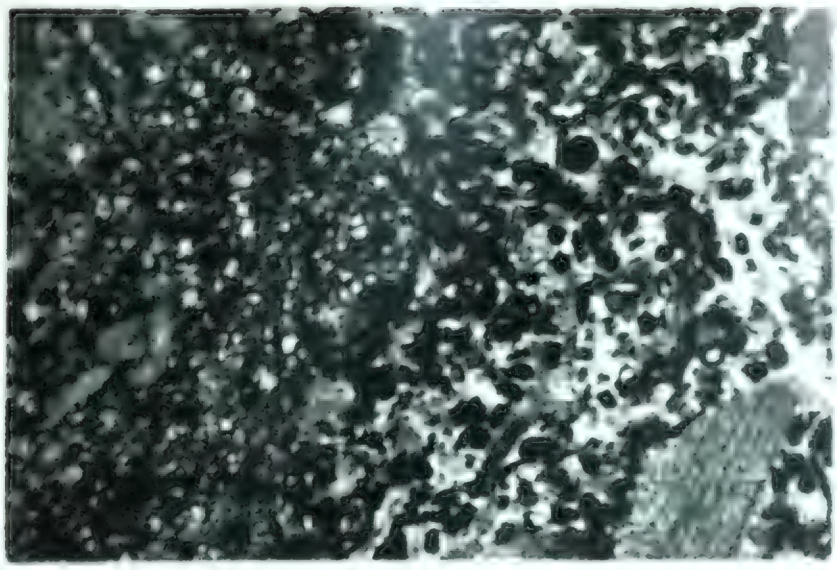
Figure 4: Biosparite; section TC 13b, Pekisko Formation, well-sorted bioclasts cemented with clear calcite. Partly rotted grains, gastropod shell in upper left, foraminifer in lower right. (x25), plane polarized light.

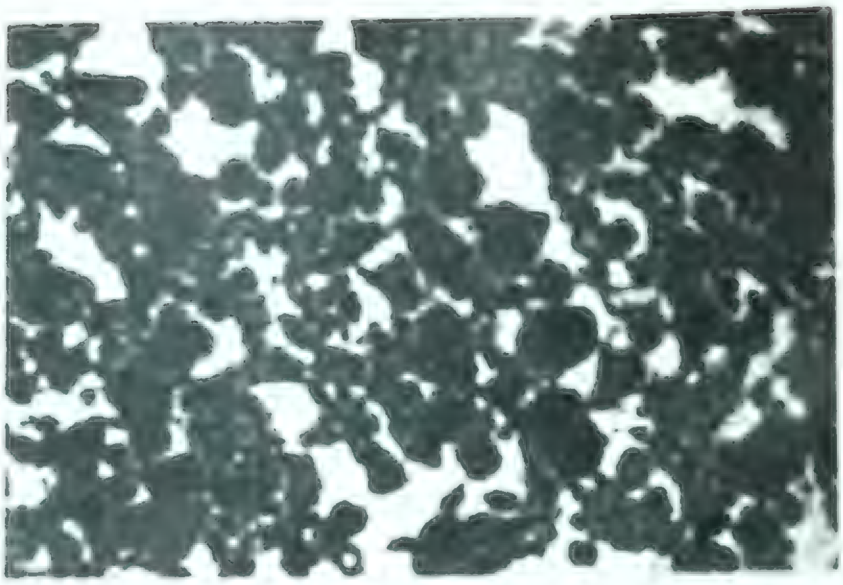
Figure 5: Dolostone; section TC 46, Mount Head Formation, type B displaying granoblastic texture. Clay minerals concentrated on microstylolite trace. (x25), plane polarized light.

Figure 6: Dolostone; section TC 12, Banff Formation, type A displaying non-uniformly sized rhombohedra and clay mineral-rich lamina. (x25), plane polarized light.

Figure 7: Conglomerate; section TC 52, Rocky Mountain Formation, colloform structure of silica (white) and phosphatic matrix (dark) with relict spicules and detrital grains. (x25), plane polarized light.

Figure 8: Sandstone; section TC 54, Rocky Mountain Formation, well-sorted, very fine-grained sandstone, silica overgrowth structures. (x170), crossed nicols.





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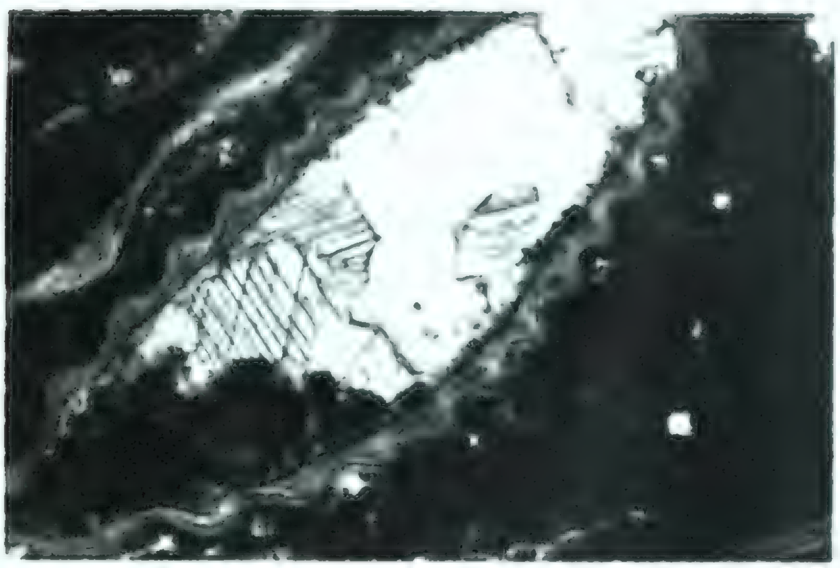

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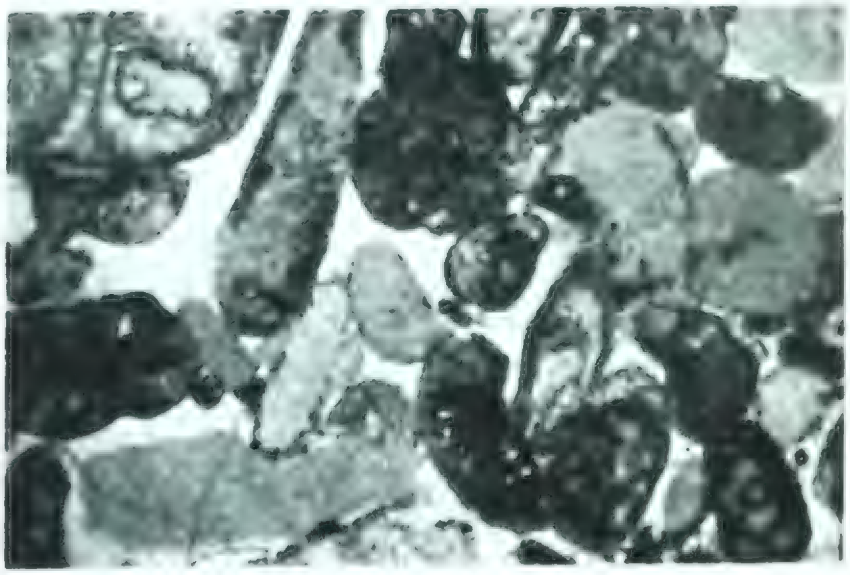

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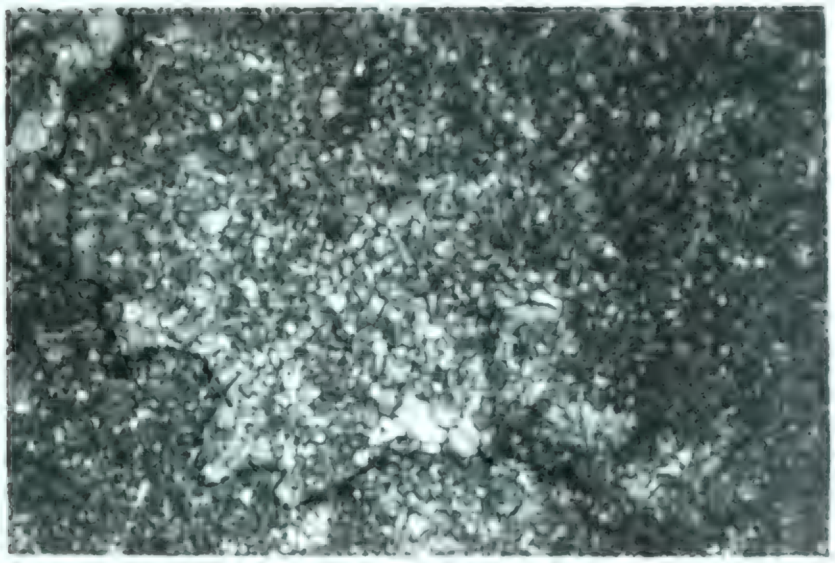

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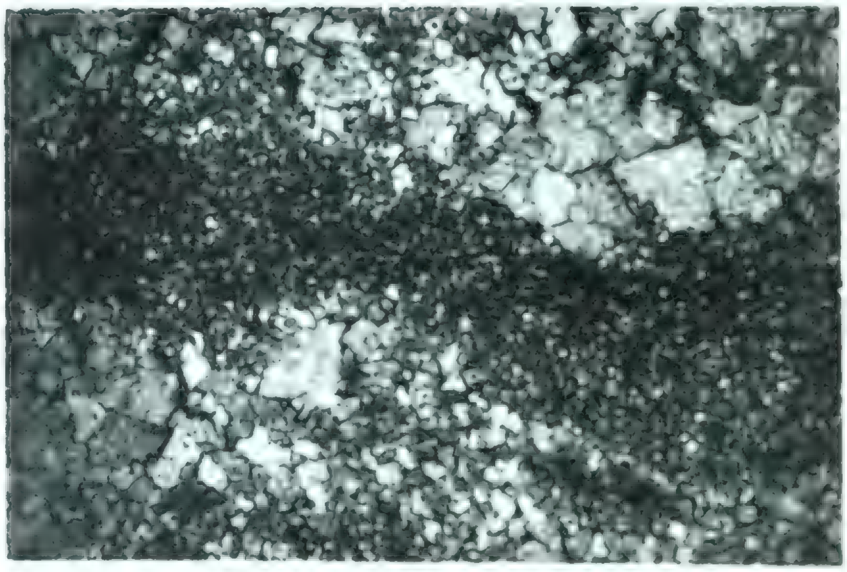

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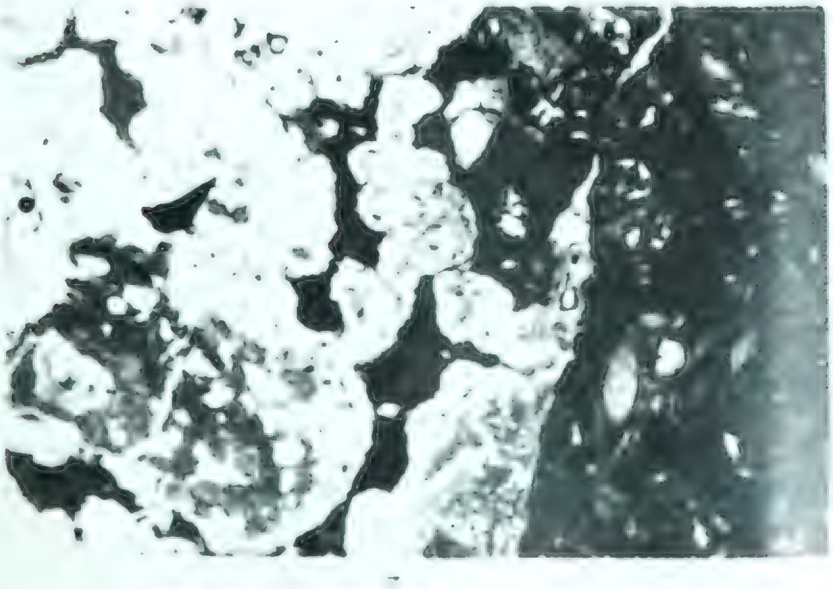

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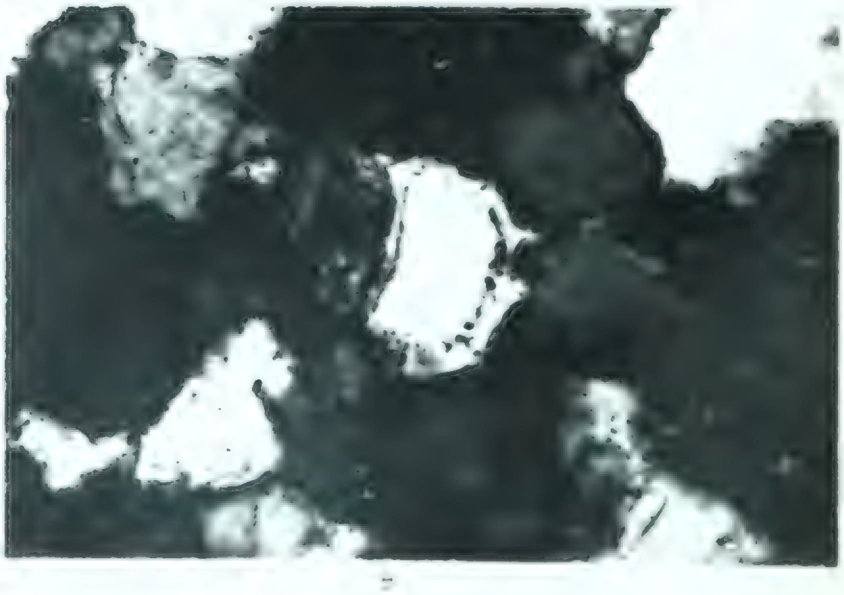

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EXPLANATION OF PLATE 2

Photomicrographs of Thin Sections

Note: all photomicrographs X25, plane polarized light.

Figure 1: Mudstone; section TC 3, Banff Formation, laminae rich in detrital quartz (white) showing fold structure formed penecontemporaneously with deposition.

Figure 2: Biosiltite; section TC 16, Pekisko Formation, poorly sorted crinoid debris in matrix of silt-sized, comminuted fossil debris. Pressure-solution welding of grains.

Figure 3: Oosparite; section TC 11, Banff Formation, oolites cemented by clear sparry calcite, high bioclast content including ostracod carapace filled with cement in lower left. A well-sorted rock.

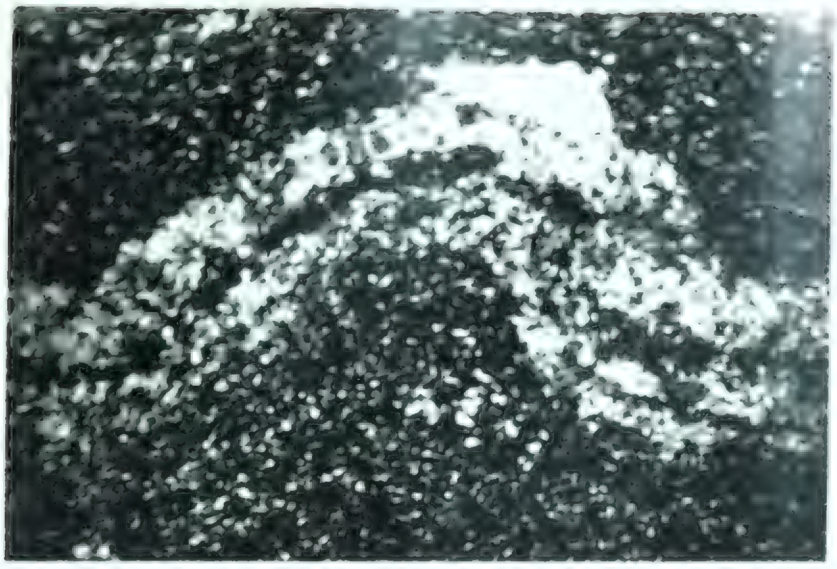
Figure 4: Micrite; section TC 31, Shunda Formation, calcite ooze containing scattered dolomite porphyroblasts.

Figure 5: Oomicrite; section TC 32, Shunda Formation, poorly sorted oolites in ooze matrix. Microstylolite traces seen by clay mineral concentrations show pressure solution effects in rock.

Figure 6: Intramicrite; section TC 20B, Shunda Formation, poorly sorted intraclasts in ooze matrix. Composite nature of intraclasts shown.

Figure 7: Biomicrite; section TC 17-13, Pekisko Formation, unsorted fossil debris in ooze matrix. Algae (dark) encrusting brachiopod shell at left.

Figure 8: Biomicrite; section TC 14, Pekisko Formation, matrix preferentially dolomitized.



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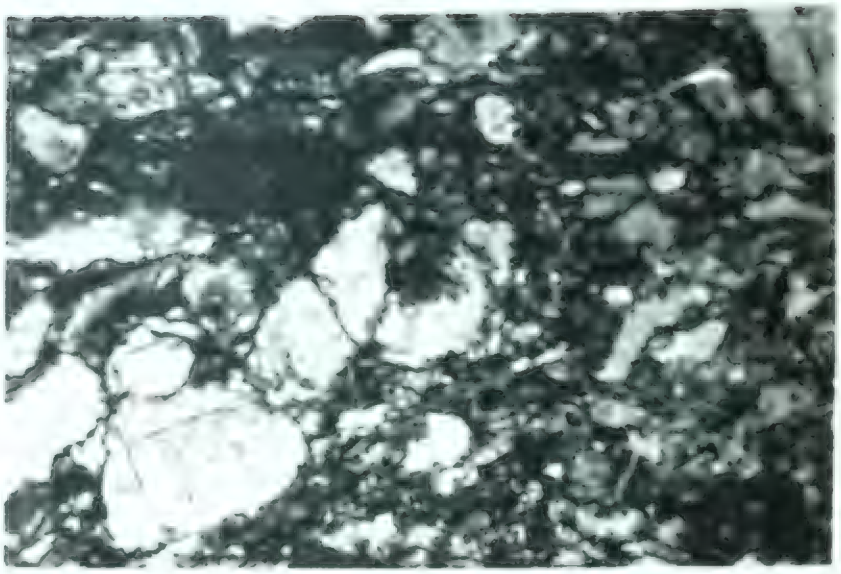

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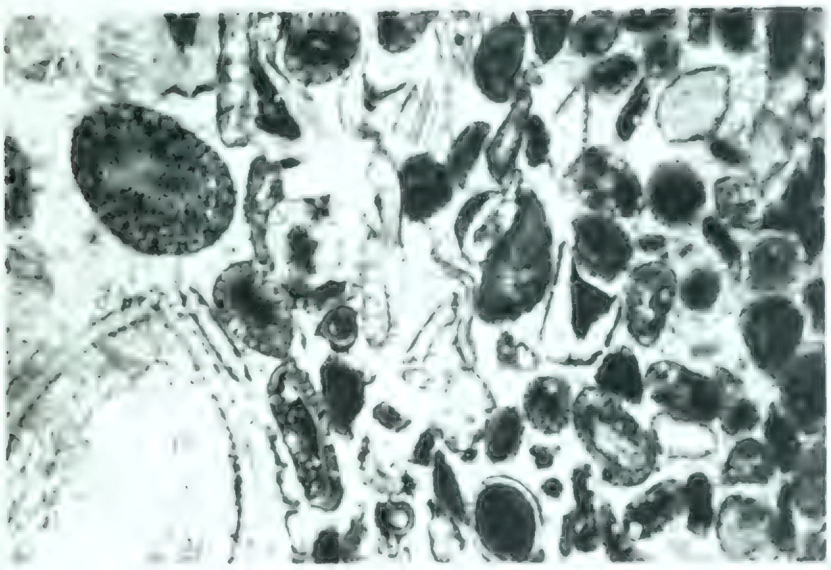

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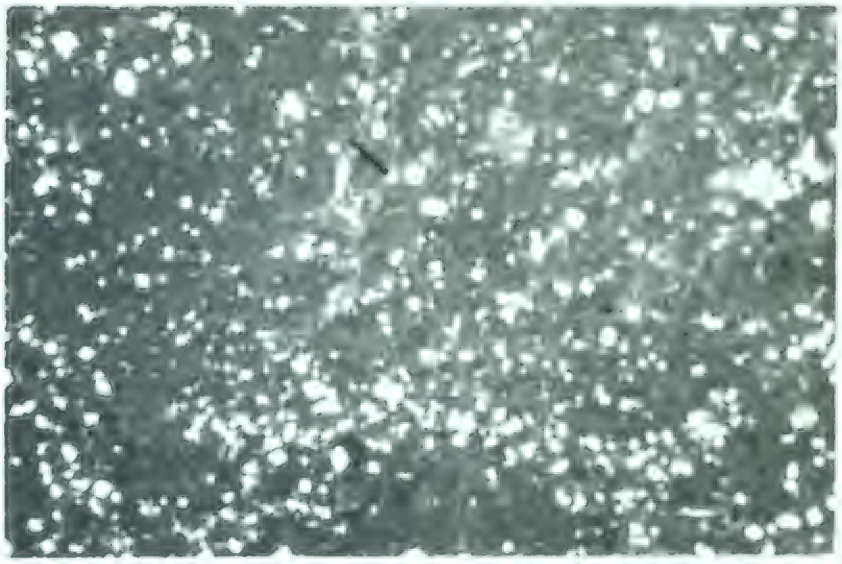

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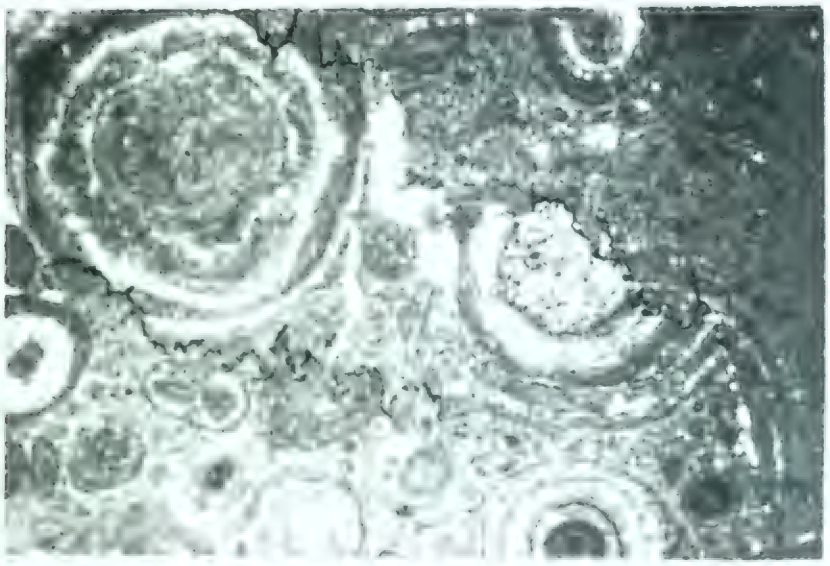

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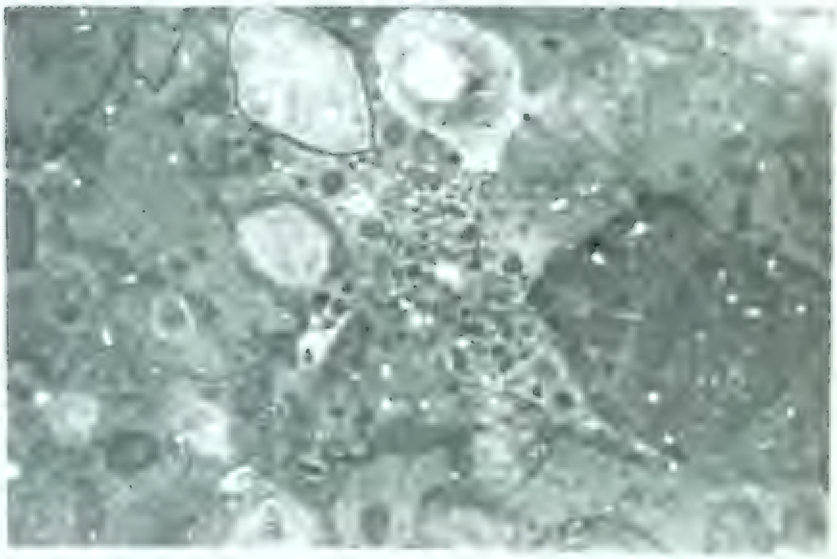

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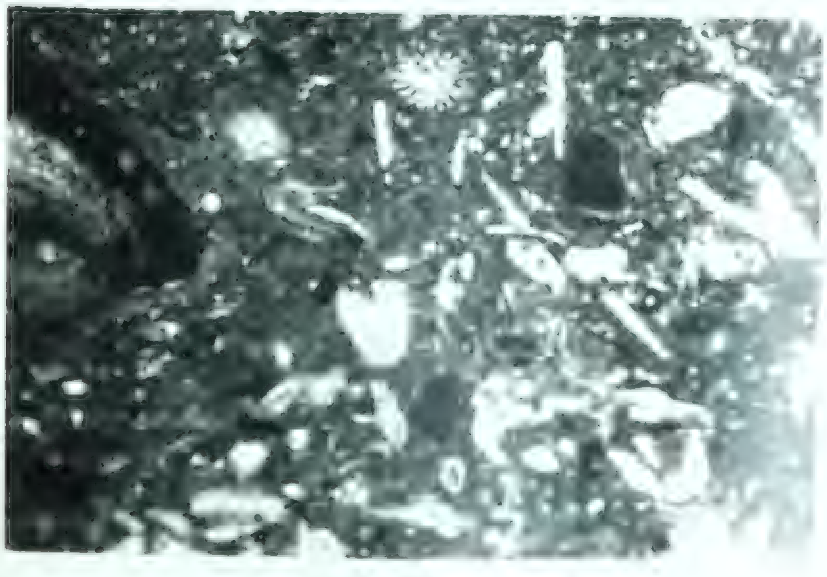

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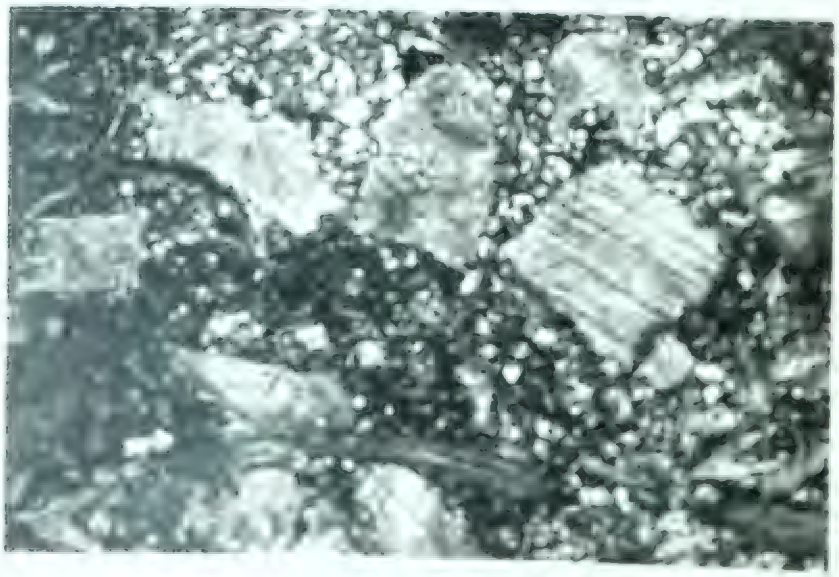
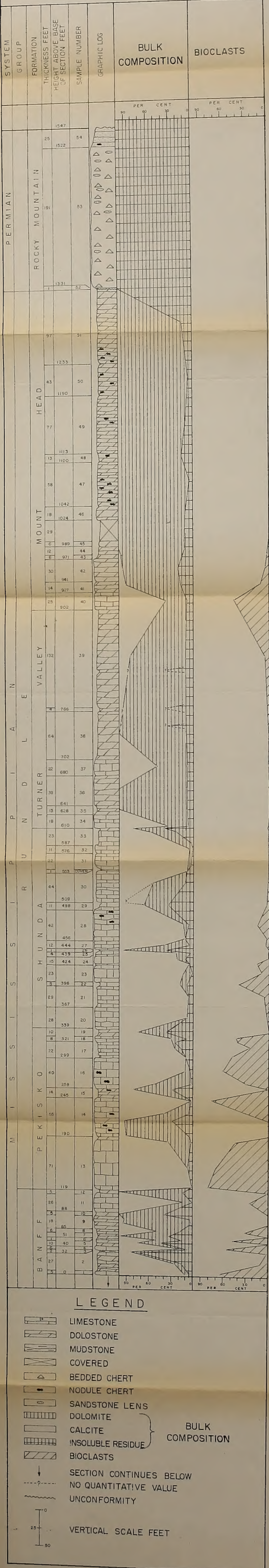


FIGURE 7
STRATIGRAPHIC COLUMNAR SECTION
THORNTON CREEK SECTION

LATITUDE 59° 9' 34" N
LONGITUDE 118° 17' 30" W



		THIN SECTION NUMBER	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7	TC 8A	TC 8B	TC 9	TC 9u	TC 10	TC 11	TC 12
		ROCK TYPE	Biosparite	Biomicrite	Mudstone	Biomicrite	Dolostone	Biomicrite	Dolostone	Dolostone	Biomicrite	Dolostone	Dolostone	Dolostone	Oosparite	Dolostone
Constituents		Calcite	93	92	38	92	44	56	0	29	50	6	7	0	89	0
		Dolomite	7	8	62	8	56	44	100	71	50	94	93	100	11	100
		Total Bioclasts	64	12	2	56	x	48		20	42	x			25	
	Bioclasts	Crinoids	53	4	x	29		47		20	39	x			19	
		Bryozoans	2	4		3		1		x	3				1	
		Algae	5	3		20										
		Echinoids	1	1		1									x	
		Brachiopods	1	x	x	1		x		x	x				x	
		Gastropods	1			1					x					
		Foraminifera													4	
		Ostracods	1	x		1					x				1	
		Calcispheres	x			x										
		Sponge Spicules														
		Corals														
		Intraclasts	4								4				6	
		Oolites	x	x		x					x				41	
		Pellets														
Inters.	Ter.	Clay Minerals	4	17	24	8	22	14	33	29	8	3	4	36	2	12
		Detrital Quartz		2	49	x	22	1	2	1				x		
	Mat.	Ooze	2	48	9	20	25	5				6	7			
		Silt-size Calcite		11		8										
		Cement	17	x	x	x		x							15	
		Porosity	2													
Texture	Mechanical	Very coarse sand									x					
		Coarse sand						x								
		Medium sand	x	x		x									x	
		Fine sand														
		Very fine sand														
		Coarse silt			x											
		Medium silt														
		Fine silt														
		Very fine silt														
		Ooze														
	Authigenic	Very coarse crystalline														
		Coarse crystalline														
		Medium crystalline														
		Fine crystalline										x	x			
		Very fine crystalline														x
		Coarse microcrystalline							x	x				x		
		Medium microcrystalline					x									
		Fine microcrystalline														
		Very fine microcrystalline														
		Cryptocrystalline														
	Sort.	Well									x				x	
		Fair						x								
		Poor	x	x		x										
	Fab.	Isotropic	x			x		x			x					
		Anisotropic								x					x	
	Pack.	Loose				x										
		Moderate	x								x				x	
		Dense														

		THIN SECTION NUMBER	TC 13a	TC 13-29	TC 13-64	TC 13-71	TC 14	TC 14-22	TC 14-32	TC 14-45	TC 15	TC 16	TC 16-5	TC 17b	TC 17	TC 17-13	TC 17-22
		ROCK TYPE	Biosparite	Biomicrite	Biomicrite	Dolostone	Biomicrite	Dolostone	Biomicrite	Biosparite	Dolostone	Biolithite	Dolostone	Biosparite	Biosparite	Biomicrite	Biomicrudite
Constituents		Calcite	100	100	63	12	60	10	63	100	32	92	49	99	100	90	97
		Dolomite	x	0	37	88	40	90	37	0	68	8	51	1	x	10	3
		Total Bioclasts	82	71	45	x	15	x	30	77		62	31	48	76	25	42
	Bioclasts	Crinoids	42	61	43	x	11	x	23	68		62	28	36	67	14	2
		Bryozoans		5	x		2		2	3				3	1	1	2
		Algae	20		2					x			x	2	5	3	10
		Echinoids		x			x		x	x					x	1	2
		Brachiopods	x	5	x		2		1				x	4	x	6	26
		Gastropods	3						3					1			
		Foraminifera	15							4			1	1	3		x
		Ostracods	1	x	x				1	2				x	x		
		Calcispheres							x	x			x	1			
		Sponge Spicules						x									
		Corals										x					
		Intraclasts	3	4						5		12	1	18	1		9
		Oolites		x	x				x					1	x	1	
		Pellets															
Inters.	Ter.	Clay Minerals	1	6	1	5	13	14	5	3	13	3	2	11	4	16	23
		Detrital Quartz								x	8	1			x	x	
	Mat.	Ooze	x	14	16		37		18	5		x	13	1		36	18
		Silt-size Calcite	x						10		25	14				11	
		Cement	13	4	x				x	10			2	20	19	2	3
		Porosity		x					1		x	x					x
Texture	Mechanical	Very coarse sand					x										
		Coarse sand	x	x	x				x	x				x	x	x	
		Medium sand															
		Fine sand										x					
		Very fine sand															
		Coarse silt															
		Medium silt															
		Fine silt															
		Very fine silt															
		Ooze															
	Authigenic	Very coarse crystalline															
		Coarse crystalline															
		Medium crystalline															
		Fine crystalline															
		Very fine crystalline															
		Coarse microcrystalline				x					x		x				
		Medium microcrystalline						x									
		Fine microcrystalline															
		Very fine microcrystalline															
		Cryptocrystalline															
	Sort.	Well	x							x							
		Fair					x								x		
		Poor		x	x				x			x		x		x	x
	Fab.	Isotropic	x	x	x		x		x	x		x		x	x	x	x
		Anisotropic															
	Pack.	Loose			x		x		x							x	x
		Moderate	x	x						x		x		x	x		
		Dense															

		THIN SECTION NUMBER	TC 18	TC 18-4	TC 19	TC 20A	TC 20B	TC 21A	TC 21B	TC 22	TC 23	TC 24b	TC 24	TC 25	TC 26	TC 27	TC 28b
		ROCK TYPE	Intrasparite	Biomicrite	Dolostone	Biomicrite	Intramicrite	Intramicrite	Biomicrite	Biomicrite	Micrite	Biomicrite	Micrite	Intramicrite	Dolostone	Micrite	Intrasparite
Constituents		Calcite	85	76	38	100	100	99	97	90	82	100	87	79	11	64	100
		Dolomite	15	24	62	0	0	1	3	10	12	x	13	21	89	36	x
		Total Bioclasts	36	44		4	x	3	12	40	9	16	2			4	3
	Bioclasts	Crinoids	23	37						34	3						x
		Bryozoans	x	2													
		Algae	3														2
		Echinoids							x			x					
		Brachiopods	3	2		1		2		2	x					1	
		Gastropods										x					
		Foraminifera	x	2					8	2	5	11	2			1	1
		Ostracods	x	1					3	1		x					
		Calcispheres	1			3	x	1	1	1	1	5				2	
		Sponge Spicules															
		Corals									x						
		Intraclasts	30	16		5	57	25				18		25			63
		Oolites	1	x		1								10			
		Pellets															
Inters.	Ter.	Clay Minerals	8	9	33	11	6	9	5	5	2	6	11	4	32	5	12
		Detrital Quartz	x		1				x	x						x	
	Mat.	Ooze	6	6	24	59	25	47	58	36	77	37	72	39	7	52	3
		Silt-size Calcite				4	x		2	6							
		Cement	11	3		9	12	15	18	1		23	3	2			19
		Porosity				5		x	x	x						6	x
Texture	Mechanical	Very coarse sand												x			
		Coarse sand		x			x										
		Medium sand						x									x
		Fine sand															
		Very fine sand	x			x				x		x					
		Coarse silt															
		Medium silt															
		Fine silt															
		Very fine silt															
		Ooze															
	Authigenic	Very coarse crystalline															
		Coarse crystalline															
		Medium crystalline															
		Fine crystalline															
		Very fine crystalline															
		Coarse microcrystalline															
		Medium microcrystalline			x												
		Fine microcrystalline													x		
		Very fine microcrystalline															
		Cryptocrystalline									x		x			x	
	Sort.	Well								x				x			
		Fair	x														
		Poor		x			x	x				x					x
	Fab.	Isotropic	x	x			x	x		x		x		x			x
		Anisotropic															
	Pack.	Loose					x	x		x				x			x
		Moderate	x	x								x					
		Dense															

		THIN SECTION NUMBER	TC 28	TC 29A	TC 29B	TC 30	TC 31b	TC 32	TC 33b	TC 33-17	TC 33a	TC 34b	TC 35	TC 36	TC 37	TC 38	TC 39
		ROCK TYPE	Intrasparite	Dolostone	Biomicrite	Intramicrite	Micrite	Oomicrite	Intramicrite	Micrite	Dolostone	Micrite	Dolostone	Dolostone	Micrite	Dolostone	Dolostone
Constituents		Calcite	93	48	50	51	95	94	75	56	26	69	0	2	57	0	18
		Dolomite	7	52	50	49	5	6	25	44	74	31	100	98	43	100	82
		Total Bioclasts	15		7	2	2		1	1		2		x	1		6
	Bioclasts	Crinoids	9		5										x		
		Bryozoans															x
		Algae															
		Echinoids			x												
		Brachiopods			2				x	x	x			x	x		x
		Gastropods			x		1										
		Foraminifera	4						1			2					
		Ostracods				x											
		Calcispheres	2				1										
		Sponge Spicules	x														
		Corals															
		Intraclasts	49		4	25	5	12	25	4					x		
		Oolites	2				2	40									
		Pellets															
Inters.	Ter.	Clay Minerals	7	31	30	11	4	2	4	24	28	7	8	9	8	9	11
		Detrital Quartz		1	2					x	8						
	Mat.	Ooze		31	23	17	76	30	44	37	18	61			51		x
		Silt-size Calcite	2														
		Cement	18				5	10	2								
		Porosity				2	1	x				2	x	x		x	4
Texture	Mechanical	Very coarse sand	x														
		Coarse sand						x									
		Medium sand			x	x			x								
		Fine sand															
		Very fine sand															
		Coarse silt															
		Medium silt															
		Fine silt															
		Very fine silt															
		Ooze															
	Authigenic	Very coarse crystalline															
		Coarse crystalline															
		Medium crystalline															
		Fine crystalline															
		Very fine crystalline											x	x		x	
		Coarse microcrystalline									x						x
		Medium microcrystalline		x													
		Fine microcrystalline															
		Very fine microcrystalline															
		Cryptocrystalline					x			x		x			x		
	Sort.	Well							x								
		Fair															
		Poor	x					x									
	Fab.	Isotropic	x					x	x								
		Anisotropic															
	Pack.	Loose						x									
		Moderate	x						x								
		Dense															

		THIN SECTION NUMBER	TC 40	TC 41	TC 42	TC 43	TC 44	TC 45	TC 46	TC 47	TC 48	TC 49	TC 50	TC 51	TC 52	TC 53	TC 54
		ROCK TYPE	Biomicrite	Dolostone	Dolostone	Dolostone	Dolostone	Dolostone	Dolostone	Dolostone	Dolostone	Dolostone	Dolostone	Dolostone	Conglomerate	Chert	Sandstone
Constituents		Calcite	69	13	9	4	2	1	1	0	0	0	0	0			0
		Dolomite	31	87	91	96	98	99	99	100	100	100	100	100			0
		Total Bioclasts	47	11	6	3	2	x	x		x	x					
	Bioclasts	Crinoids	45	x	x	x	1					x					
		Bryozoans	2	x		x	x										
		Algae															
		Echinoids															
		Brachiopods		x			x	x									
		Gastropods															
		Foraminifera															
		Ostracods															
		Calcispheres															
		Sponge Spicules													x	x	
		Corals			x			x									
		Intraclasts															
		Oolites															
		Pellets															
Inters.	Ter.	Clay Minerals	8	9	19	12	10	9	8	3	19	9	2	10			
		Detrital Quartz									x			1			75
	Mat.	Ooze	16														
		Silt-size Calcite															
		Cement			x												2
		Porosity	x		10	10				x		12			3		6
Texture	Mechanical	Very coarse sand															
		Coarse sand	x														
		Medium sand															
		Fine sand															
		Very fine sand															x
		Coarse silt															
		Medium silt															
		Fine silt															
		Very fine silt															
		Ooze															
	Authigenic	Very coarse crystalline															
		Coarse crystalline															
		Medium crystalline															
		Fine crystalline										x					
		Very fine crystalline			x	x				x							
		Coarse microcrystalline		x			x		x				x	x			
		Medium microcrystalline						x									
		Fine microcrystalline									x						
		Very fine microcrystalline															
		Cryptocrystalline															
	Sort.	Well															x
		Fair															
		Poor											x		x		
	Fab.	Isotropic											x		x		x
		Anisotropic															
	Pack.	Loose											x		x		
		Moderate															
		Dense															x

x Indicates Trace Amounts or Presence

Numerals indicate percentage

THIN SECTION DATA

B29803